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WYE COLLEGE

Department of Hop Research

ANNUAL REPORT

1961

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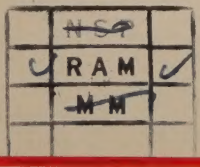

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INTRODUCTION

EXPERIMENTS with hops have been carried out continuously at Wye for nearly 70 years. In 1948 this work was reconstituted and given the status of a separate department—the Department of Hop Research. This fourteenth annual report of the Department indicates that the attention paid to the problems of this small but important crop grows no less with the passing of time; hop research is still one of the more important activities of the College.

The scope of the work is indicated in summary form by a review article on page 1 and also by the accompanying leaflet, written specifically for the non-scientific reader. The Department continues to make satisfactory progress in its investigations on many problems of major importance to the hop grower. New varieties are being developed to overcome disease and to meet modern demands for hops that will suit the picking machines and will brew lager beer. The ill-defined characters that decide the delicate but all-important questions of aroma and quality are reluctantly yielding to identification by new chemical techniques. Field experimentation, hop engineering, disease and pest control, growth and propagation are all the objects of well planned research effort. This effort is strengthened by extensive collaboration enjoyed with East Malling Research Station, the National Institute of Agricultural Engineering, the Brewing Industry Research Foundation and the National Agricultural Advisory Service.

No staff changes took place during the year under review. It is with great regret, however, that we record the tragic death of Dr. I. H. Williams in April 1962. Appointed to the Department in 1957 for research in hop growth, he rapidly made important contributions to our understanding of the crop that are of both practical and fundamental value. The sadness of his death is increased by its occurrence on the eve of his accession to the Chair of Horticulture at Khartoum University, a major appointment which he was expected to fill with distinction.

Although not falling strictly within the year under review, it is with much regret that we record the forthcoming retirement of Mr. F. H. Beard and resignation of Dr. Harry Darling. Mr. Beard, trained at Wye College, worked for 23 years at East Malling Research Station and in 1949 joined the staff of the Hop Research Department at Wye as Field Officer. His wide knowledge of the

hop crop under field conditions will be greatly missed and his colleagues wish him well on his retirement in September.

Dr. Harry Darling was appointed Head of the Department in 1954 after a distinguished career in applied entomology largely overseas. During the war he was engaged on locust control work in Persia and Arabia, and subsequently served in Uganda on cotton pest control, in the Sudan as research entomologist in a similar field and, before coming to Wye, as Senior Lecturer in Entomology at the University of Khartoum. He leaves us to take up the very responsible position of Professor and Dean of Agriculture at the Ahmadu Bello University of Northern Nigeria at Zaria, Northern Nigeria, a post which he will combine with that of Director of the important Agricultural Research Station at Samaru. He will be very greatly missed by all his friends and colleagues and the College desires to place on record its appreciation and gratitude for all that he has accomplished at Wye during the eight years in which he has served as Head of the Department of Hop Research. Under him a young and vigorous team of research workers has been built up and the relationships of the Department both with hop growers, at home and overseas, and with sister research institutions has never been better than under his wise and kindly guidance. He has, in full measure, that rare combination of scientific probity and a deep understanding of human nature, both welded together with a rich sense of humour which no doubt he owes to his Northern Irish antecedents. His post is one which will be difficult to fill as adequately as he has filled it, but the College takes pleasure in the knowledge that his rare qualities and wide experience are to be used in such an important field. To him will fall the responsibility of instituting higher education in agriculture in Northern Nigeria and of developing research in that context, and it is primarily upon agricultural production that the whole of the economy of Northern Nigeria depends not only for its development but even for its survival.

The thanks of the College are most warmly expressed once again to the Agricultural Research Council, the Hops Marketing Board and the Institute of Brewing for their continued support throughout the year. This support has been rendered the more welcome and encouraging by reason of the keen interest which these bodies continue to take in the activities of the Hop Research Department.

DUNSTAN SKILBECK.

July, 1962

REVIEW OF RESEARCH

H. S. Darling

In the review of research which prefaced the 1955 Annual Report of the Wye College Hop Department, mention was made of five major scientific problems then confronting the English hop grower. These were: progressive *Verticillium* wilt, nettlehead virus, downy mildew disease, harvesting by machine and the maintenance of soil fertility. Seven years later, while the first three of these are still of acute importance, the remaining two have lost much of their urgency through research and experience. A sixth problem has arisen in recent years in the form of an ever-increasing demand for hops for lager brewing, a demand which the English grower is at present unable to meet.

Research on the pathology of progressive wilt and on the nettlehead virus problem remain the responsibility of East Malling Research Station. It gives pleasure to note that steady progress has been made in these difficult fields of research and much more information is now available than when the 1955 report was written. This opportunity is taken to congratulate the workers at East Malling on the successes achieved in their investigations.

The wilt problem is now more serious than ever before, and from the growers' point of view the present answer to it, in infested areas, lies in the use of tolerant hop varieties which show considerable field resistance to the disease. The production of suitable tolerable varieties is a plant breeding problem on which much research is being carried out at Wye College; current progress in this research is reviewed in detail on page 13 of this report. The original tolerant varieties which saved the situation for growers on wilt farms in the difficult decade of 1947-56 were Keyworth's Early and Keyworth's Midseason, both raised at Wye in the course of earlier breeding work on other problems. These varieties have been finally rejected by the brewers as unsuitable in quality to be a long-term answer to the wilt problem; they have been largely replaced by Whitbread's Golding Variety (raised by Mr. White at Beltring in 1911) and by Bramling Cross (raised at Wye in 1924) which are the most popular tolerant varieties at the present time. Of these two, the former suffers from the major disadvantage of great susceptibility to downy mildew attack in the rootstock; the latter has yet to win unqualified approval from the brewing industry.

Janus, Density and Defender, raised at East Malling some eighteen years ago, are now coming into commercial production; they were released to growers as "stop-gap" varieties to help meet the need for a tolerant hop acceptable to both grower and brewer. While of considerable intrinsic merit, these seedlings are expected to be superseded in a few years by varieties from the Wye/East Malling Joint Scheme which was begun in 1950 and of which the most promising selections are now undergoing large-scale farm and brewing trials.

Plant breeding work at Wye is also concerned with two other projects of immediate interest to growers. These are first, the production of commercially acceptable varieties that are resistant to downy mildew: and second, the development of varieties that under English conditions will yield hops suitable for lager brewing. Both of these projects represent long-term research and both are based on material from central Europe. With hops for lager beer, lack of seeds in the cones appears to be of major importance. Here, the polyploid breeding techniques developed at Wye are expected to be of advantage in producing triploid varieties of inherently low seed content even when grown under English conditions of full pollination. One triploid variety, raised in the course of other research and not specially bred for use in lager beer, is in farm trials and is already exciting interest among English brewers.

The hop breeder is handicapped by inability to assess directly those factors in the male hop which influence cone quality in its female progeny. This difficulty is slowly being overcome at Wye by progeny testing of males; the work has been much helped by the reorganization of the nursery garden area, completed in 1956, which has greatly facilitated the making of comparative observations on whole seedling families. As a result, preliminary distinctions have been made between male parents which should increase the probability of raising wilt-tolerant seedlings of the type expected to prove acceptable to the brewer.

Brewing quality in hops, in spite of many years of research, remains a subject which is as obscure as it is fascinating. The soft resins are generally agreed to be of prime importance. Twenty years ago this importance was mainly related to their bacteriostatic action, i.e. preservative value or PV. Now, with increasing emphasis on sterile brewing conditions and on pasteurization, it is generally accepted that the most valuable function of these soft resins is to give to beer its characteristic bitter taste. When the 1955 review of research was written, it was assumed that knowledge of the chemistry

of the bittering agents in the soft resins was largely complete, and that an era was beginning in which hop utilization could be standardized in terms of the content of identified bittering compounds in the beer. This assumption has since proved to be more optimistic than correct, and the chemistry of hop resins in relation to their bittering power in beer is under extensive review at the Brewing Industry Research Foundation in England and in similar brewing research organizations in other countries.

A second aspect of hop quality of much importance in brewing lies in the hop oil fraction; this is held to be mainly responsible for the aroma and delicate background flavour in beer which are highly esteemed by the discriminating drinker. Research is being carried out at Wye on hop oils and this is discussed on page 21 of the ensuing report. It has been shown that cones without seeds have an increased hop oil content which may give a clue to the preference of lager brewers for seedless hops. Because of the low specific gravity of lager beer, its hop rate is of necessity less than in normal English ales. The relatively small amount of seedless hops used, however, introduces a much larger quantity of oil than would be the case with seeded hops and may thus account for the flavour pattern said to be characteristic of lager beer.

Where flavour is concerned, quality is as important as quantity. The hop oil fraction of dried cones is a complex mixture of at least one hundred compounds which may differ widely in their effect on beer flavour, and which are present in varying proportions according to the genetic make-up of the variety. Research on this difficult but important subject has been much assisted by gas chromatography techniques, and the results of preliminary examinations of the oils of commercial varieties are given on page 21. This work is being further developed to facilitate the selection of new seedlings raised in hop breeding research.

Reference to current hop breeding at Wye would not be complete without mention of selection work in Golding and Fuggle clones, and of the International Variety Trial recently begun under the auspices of the Liaison Committee of the European Brewery Convention. These lines of research are discussed in a review of field experimentation on page 17. The work with Golding clones is nearing completion and recommended selections, which give a sequence of ripening dates to assist in machine picking, are to be released to the Industry in the winter of 1962-63. The Fuggle clone project still awaits completion, having been much delayed by the wilt outbreak at the College in 1954-56.

The International Variety Trial, in which the Scientific Commission of the European Hop Growers Committee is collaborating at present involves six varieties: two from Germany, two from Great Britain and two from Denmark. All six varieties are being grown at a number of sites in hop growing areas of Europe with the object of comparing their performance under a range of climatic and cultural conditions. Preliminary results indicate that the English varieties, Northern Brewer and Fuggle N, are not inferior in yield or resin content to their continental counterparts.

The gravity of the wilt problem to the English grower is increased by two factors: first, the existing shortage of planting material of tolerant varieties, and second, by the risk of loss of basic quota through depressed yields. Over the last three years, research at Wye on mist propagation has made available to the Industry a new technique which is helping to reduce the bottleneck in the supply of planting material by increasing the output of professional hop propagators in East Anglia and elsewhere, and by enabling grower-propagators to supplement their existing production of setts. With the death of Dr. Williams this research has temporarily stopped; the data he obtained in 1961 are summarized on page 34.

The necessity to maintain yields for quota purposes gives added interest to the article on page 59 which discusses the results of recent research on some aspects of the cultural management of young hop plants. The rate of establishment of a young rootstock and its yield of hops can be adversely affected by stripping off the lower mainstem leaves for pests and disease control and by cutting the bine for machine picking. Of these two practices, the stripping of leaves would appear to have the more serious effect. For growers, wrestling with the wilt problem, the extensive replanting of hop gardens is an unfortunate necessity; under such conditions, if quota is to be kept, the loss of yield through replanting must be minimized and here the value of such research is apparent.

Downy mildew disease remains costly to the grower because of heavy annual expenditure on routine preventive control measures. In spite of such measures, downy mildew can still cause serious damage to the crop, as recorded in Appendices II and III which give a general account of English hop production in 1961 and which are published by kind permission of the National Agricultural Advisory Service. Since 1955, our knowledge of this disease has been substantially increased by research at Wye, current progress in which is reviewed on page 32. It is now known that downy mildew can live and overwinter in the rootstock, and the clear establishment

of this fact has made possible two firm lines of approach to the problem. First, steps are being taken to ensure that planting material is raised under disease-free conditions so that setts are not already infected when they reach the grower. This point is perhaps the most important of the many in favour of buying setts that are produced under the A-Plus Certification Scheme of the Ministry of Agriculture, Fisheries and Food. Second, techniques are being developed to reduce the incidence of downy mildew by preventing the fungus from establishing itself in the rootstocks of clean plant material. Research at Wye College has shown the efficacy in this connection of hill dusting with Bordeaux powder. Support for this is indicated in the results of field trials carried out by the N.A.A.S. which are described in Appendix IV.

Investigations continue at Wye to determine the most efficient hill dusting programme during the growing season for adequate control of downy mildew infection in the rootstocks under field conditions. Other fungicides are being tested in addition to Bordeaux powder. Trials are also being carried out in gardens with infected rootstocks to see if the action of fungicidal dusts will control the development of early secondary infections and so reduce the necessity for spiking—a time-consuming and expensive operation. It may be mentioned here that in the experience of the Department, it is desirable to maintain a cover of protective fungicide on the young bine tissue from the time growth begins in the spring. Hand spiking and the stripping of infected leaves, though essential operations, do not by themselves give adequate control of downy mildew in the spring and early summer.

Studies are commencing on the climatic factors which influence the development and spread of downy mildew disease under field conditions. A new isolation garden, in which fungicides are not normally applied, is being used for this work and the necessary meteorological and spore trapping equipment has been installed.

The problem of the maintenance of soil fertility in hop gardens is primarily one of soil structure, and here difficulties appear to be less acute than formerly. This improvement is possibly due to greater availability of farm-yard manure (the traditional and best answer to the problem) and to new techniques such as straw mulching. Attempts to provide an answer by grassing down in place of continuous arable cultivation have not yet been successful. Research on grassing down of hops, initiated at Wye ten years ago, still continues and a field-scale replicated trial is being carried out by the N.A.A.S. at Rosemaund Experimental Husbandry Farm near

Hereford. It is of interest to note in this connection, that one grower with a large acreage is increasing his area of grassed down hops with the joint objects of improving soil conditions and of restricting the spread of progressive wilt. In this case grassing down is combined with irrigation to reduce the adverse effect of competition for water by the hops and the sward.

Less immediately important than the problem of soil structure, but of great long-term significance, is the question of hop manuring; i.e. the N, P and K nutrition of hop gardens. This is under examination at Wye and the results of recent research are reviewed on page 19 and are also the subject of a paper on page 44. These results indicate that once a hop garden is established under conditions of high soil fertility, yields can be maintained by much smaller dressings of fertilizers (especially phosphates) than normally given by many growers. Inherent in these findings is the assumption that growers make use of the excellent soil analysis services given by the N.A.A.S. to check the manurial status of their hop gardens in respect of N, P and K.

As with soil fertility, the problems associated with hop engineering appear to be less acutely felt than formerly. While this improvement is due in part to increasing experience of mechanization on the part of the growers, it is also due to the major contribution to research on hop problems made in recent years by the National Institute of Agricultural Engineering. Current progress in this research, to which Wye College is also committed (one of the Wye staff is on permanent secondment to the N.I.A.E. for this purpose), is reviewed on page 36. While machine picking remains the main subject of these investigations, hop wirework is receiving attention; basic knowledge on the strains and stresses in wirework systems is slowly being accumulated and causes of failure in commercial practice are under examination. Research on hop drying is also the responsibility of the N.I.A.E. and it is likely that renewed interest will be taken in drying problems in the future.

Research on machine picking at Wye in recent years has had two main objectives. First, the development of techniques for harvesting experiments by machine, and the establishment of the nature and size of the errors to be expected when a machine is so used; and second, improvements in the commercial performance of picking machines. The first objective is of great importance; more so than may be immediately apparent. All hop research is related to field practice, and all field experiments depend ultimately on yield data to establish their results. Hop research centres everywhere

are inevitably conforming to commercial practice and are harvesting their experiments by machine. It is essential that the limits of accuracy of mechanical picking be firmly established, otherwise many important aspects of hop research may become little more than a meaningless extravagance. Pioneer experiments have been carried out at Wye in recent years on this crucial subject and the final progress report on this work is given on page 69. It can now be said with confidence that mechanical picking, if carried out with suitable care, is as accurate for experimental purposes as good hand picking. As a result of these findings Wye has increased its picking machine capacity and it is planned to harvest the whole of the College crop mechanically in 1962.

Three main lines of research are aimed at improvements in picking machine performance. First, the working of the machine itself is under examination; second, aspects of the cultural management of the crop which affect its suitability for machine picking are being investigated; and third, the physical handling of hop plant material to and from the machine has received attention. Research on the technical aspects of the working of the machine is reviewed on page 36. Techniques are being devised by which standardized tests can be carried out, and information is being accumulated on the most important topic of sample cleaning.

Investigations on cultural management are included in the height of wirework and spacing trial, now in its fourth year, which is discussed on pages 69 and 75. The results obtained confirm what has been learned empirically by many growers, that the prime requisite in growing hops for the machine is to avoid the development of any form of tangled head to the bines. The obvious answer here, is to provide the plants with a greater length of string for growth; the Wye results indicate that this is more economically achieved in terms of yield per acre by raising the height of the wirework than by increasing the width of the spacing.

The physical handling of plant material to and from the picking machine has been investigated by Mr. D. G. Martin, holding a postgraduate scholarship generously provided by the Hops Marketing Board. The substance of Mr. Martin's thesis is summarized in an article on page 79. In the experience of many growers, including workers at Wye, the most difficult task in mechanical harvesting is to maintain at the machine a regular and adequate supply of fresh bines in good condition for picking. Mr. Martin has made an intensive study of all methods currently used in England for handling and transporting bines from the garden to the machine. His findings and

comments are inevitably cautious but the impression is gained that English growers will follow their American counterparts in developing a system in which workers in mobile crow's-nests carefully cut the strings from the top wire and allow the bines to fall gently by gravity along the length of the transporting vehicle.

The disposal of waste plant material from hop picking machines was investigated by Mr. Martin in connection with the possible spread of progressive wilt infection. Attention was paid to the normal practice of composting such waste residues with special reference to the temperatures developed in the compost heaps. It was found that the centre of each heap investigated heated to temperatures lethal to the wilt fungus, and that if composting was carried out with care it could be relied on to eliminate most of the infection originally present. This work (in which East Malling Research Station collaborated) has been of great assistance to the special working party set up by the Agricultural Research Council to advise on the safe disposal of plant residues from hop picking machines in wilt-infested areas.

Thanks to modern systemic insecticides, the hop aphis is no longer a problem. The two insecticides in common use by hop growers are demeton methyl and dimefox. Both of these give excellent control under English conditions of the hop aphis and the hop red spider. Work at Wye has shown, however, that the use of dimefox gives a yield increase of more than one cwt. of dried hops per acre compared with demeton methyl. This yield increase does not appear to be due to greater insecticidal efficiency on the part of dimefox and the reason for it is not at present known. This work at Wye, which is discussed on page 26, has also shown that the use of systemic insecticides is responsible for an increase in the number of bushels of green hops required to give a hundredweight of dried hops. This finding has lost much of its importance through the rapid increase in machine picking, which means that harvesting costs are no longer a function of the volume of green hops picked.

Dimefox is markedly toxic to some hop varieties. An article on page 39 describes a technique developed at Wye to screen new seedling material for susceptibility to dimefox poisoning. All new varieties will be so tested before commercial release.

In addition to its work on English hop problems Wye College has maintained its interest in hop research overseas through the Scientific Commission of the European Hop Growers' Convention and through the Liaison Committee of the European Brewery Convention with which the Scientific Commission is connected.

The Liaison Committee met in Dublin in February 1962 when the College was represented. A representative of the College will also be present at the full session of the Scientific Commission to be held in Madrid in August 1962.

The College has maintained its essential contacts with the English Hop Industry through the appropriate committees and other channels of the Hops Marketing Board, the Institute of Brewing, the National Agricultural Advisory Service and the Association of Growers of the New Varieties of Hops. It has also strengthened those personal links with both growers and brewers which help to maintain a balanced outlook and a sense of perspective. Staff have attended meetings of working parties of both the Agricultural Improvement Council and the Agricultural Research Council, and also meetings of the Rosemaund Farm Advisory Committee. They have also given lectures on their work to conferences and meetings of growers and to other interested bodies.

Thanks are expressed to the National Institute of Agricultural Engineering, to East Malling Research Station and to the Brewing Industry Research Foundation for co-operation enjoyed during the year. Thanks are also due to growers, factors, merchants and other friends of the College who have helped in departmental research. Grateful acknowledgement is made to the National Agricultural Advisory Service for help given in the maintenance of quarantine gardens and out-stations in the Stratford-on-Avon and Cambridge areas.

REVIEW OF THE 1961 HOP SEASON AT WYE COLLEGE

H. S. Darling

The 1960-61 winter at Wye was mild and very wet. The rainfall for October—February totalled 24·55 inches compared with the 26 year average of 15·50 inches for the same period. Wet conditions hindered routine winter work: lack of frost together with the high rainfall and enforced late ploughing adversely affected soil structure in all hop gardens. Meteorological data for Wye for 1961 are set out below; mean values for the 27 year period 1935-61 are given for comparison.

	Rainfall Inches per month		Sunshine Hours per day		Mean Temperature °F	
	1961	1935-61	1961	1935-61	1961	1935-61
January ..	3·77	3·01	2·07	1·75	38·7	38·1
February ..	2·62	2·39	2·77	2·53	44·3	38·8
March ..	0·10	1·77	5·42	4·16	45·3	43·1
April	2·23	1·59	3·88	5·76	49·8	47·7
May	1·18	1·88	8·38	7·01	52·0	53·0
June	1·17	1·77	8·32	7·49	59·0	58·7
July	1·50	2·23	5·90	6·73	61·2	61·8
August ..	0·73	2·60	5·80	6·26	61·5	61·7
September ..	2·14	2·35	4·81	5·09	61·2	58·2
October ..	4·38	3·39	3·85	3·70	53·3	51·2
November ..	3·32	3·65	2·44	2·14	43·7	44·6
December ..	3·31	3·08	2·40	1·59	38·9	40·4
Total ..	26·45	29·71				

Warm wet weather in April encouraged an epidemic attack of hop downy mildew which continued into June; control was eventually established by the extensive use of fungicides and by much stripping and spiking. Severe damage was caused to the young bines and the removal of terminal spikes in susceptible varieties adversely affected their growth. Downy mildew caused no further trouble during the rest of the summer.

Growth was further checked in May by heavy aphis attacks and by late frosts which (following on a mild winter) caused young

plants to go dormant. The aphis attacks began on the exceptionally early date of 4th May and were satisfactorily controlled by systemic insecticides. The effects of frost damage were slow to disappear and many of the affected plants did not resume normal growth for several weeks.

The crop made sustained and satisfactory growth during the second half of June and during July. The summer was very dry, the drought being especially pronounced during late July and August when less than one inch of rain fell in the six weeks ending on August 31st. This drought did not bring high temperatures but was accompanied by cloudy days and strong winds. Conditions during August did not favour the production of a good hop crop.

The dry summer weather encouraged mould disease which was potentially serious. Good control was achieved by repeated application of karathane sprays and sulphur dusts, but some damage was caused to susceptible varieties such as Northern Brewer.

No case of *Verticillium albo-atrum* in hops was recorded on the College farm during the year under review.

From the beginning, the 1961 growing season was not conducive to high yields. Adverse soil conditions, bad weather and disease combined to limit the size and quality of the crop. Of these three factors it is probable that the most important was unfavourable weather in August. Yields from all varieties were much lower than in the previous season. Mature plants gave up to 20 cwt. per acre compared with 25 cwt. per acre in 1960. The College crop totalled 280 cwt. as weighed at the oast after drying. Half the crop was picked by machine. Details of yields for 1961 and 1960 are given below:

	1961	*1960*
	cwt.	cwt.
Goldings	48·5	55·0
Fuggles	47·5	53·5
Northern Brewer	80·5	109·5
Bullion	66·0	80·5
W.G.V.	6·5	8·5
Plant Breeding Hops	31·0	52·0
	280·0	359·0

The isolation garden for research on downy mildew and other hop diseases was planted in 1961, permanent wirework being erected during the winter of 1961-62. This garden is situated on the eastern edge of the College farm and has been named Little Sparks. It has been equipped with meteorological and other apparatus to study factors influencing the incidence of downy mildew and mould diseases.

PLANT BREEDING SECTION
REVIEW OF THE YEAR'S WORK

R. A. Neve and R. F. Farrar

The farm trials of the three varieties selected from the Wye/East Malling Joint Scheme were harvested for the first time, and the hops have been sent to various breweries for large scale brewing trials organized by the Institute of Brewing. The three varieties, and a control variety, have been sent under code letters to eliminate bias in the results.

The triploid variety, WFT2, was planted up by two growers in the South-East, while a sample from one of the West Midland trials caused considerable interest when shown at the Exhibition of New Varieties of Hops. Col. Richardson has distributed the small quantity available to lager brewers at home and on the Continent.

Wilt Testing

Wilt testing of new seedlings was continued at East Malling Research Station. The material submitted consisted of diploid male and triploid female seedlings. Amongst the latter, one seedling of tetraploid Fuggle and two of tetraploid Eastwell Golding appeared to be at least as tolerant as Keyworth's Midseason (OR55). While it is encouraging to find that such levels of tolerance can be found in triploids from these parents, the results still indicate that they occur much less frequently than in corresponding diploid families.

Results of Breeding Programme, 1956-59

The re-organization of the Nursery Garden, which was carried out to make possible the evaluation of the parent plants used in the breeding programme, was completed in 1956. Since then information has been accumulating so that it is now possible to summarize the results of initial selection on the families raised in the years 1956-59. During this period six of the wilt tolerant males then available were used to pollinate diploid and tetraploid clones of Fuggle, Eastwell Golding and Early Bird, and diploid Saaz, although it was not possible to cross these in all combinations.

From these families a total of 140 diploid and 151 triploid seedlings were selected as promising, judged by characters other than wilt tolerance, which is assessed during the next stage of selection.

These figures represent 8·0 per cent. of all the diploid seedlings and 5·6 per cent. of the triploids.

One of the reasons for embarking on a polyploid breeding programme was that a higher selection rate was anticipated from triploid seedlings and it is important to consider why this has not been obtained.

Although more than one factor appears to be involved, a detailed study of the records indicates that time of maturity is the most important consideration. It has been consistently noticed that triploid seedlings mature later, on the average, than diploids of the same parentage. Triploids from late maturing parents are mostly judged to be too late although the corresponding diploids might be acceptable. With the earliest maturing male parent (No. 321) there was in fact a higher selection rate amongst triploids but with the latest maturing male (No. 15) the position was reversed.

In diploid crosses, male 15, which differs from all the others in not having any American parentage, was outstandingly successful with an overall selection rate of 27 per cent. compared with only 9 per cent. for the next best male. In triploid families this advantage disappeared, largely because of the lateness factor, and male 15 was no more successful than three of the other males, except when crossed to the earliest female, Early Bird.

When mosaic sensitive Goldings were used as the female parents a higher incidence of mosaic was recorded amongst triploid families. This supports the prediction that triploids would show a greater resemblance to their female parent than would diploids, but it has nevertheless contributed to the lower selection rate of triploids.

The third factor which has been noticed is the failure of triploids to crop well on the lower part of the bine. In some triploids this has caused them to be rejected. In others it is not so serious, but must nevertheless represent a loss of crop. Experiments are planned for 1962 to see whether this behaviour can be modified by training different strength bines.

Selection of Improved Males

The big differences in performance of the various males indicate how important it is for further progress that more suitable males should be selected and tested, and this part of the programme has progressed well.

As reported last year, four male seedlings of Eastwell Golding × OB79, which appeared to be wilt-tolerant in a 3-plant test, were used

to pollinate Whitbread's Golding Variety (1147). The progeny of one of these males was found to contain such a high proportion of useless male triploids (resulting from unreduced pollen grains) that this male was dropped from the 1961 programme. The three remaining males were used to pollinate three of their full sisters which have also shown no wilt in a 3-plant test. They were also crossed with tetraploid Whitbread's Golding Variety.

Another group of males underwent 30-plant wilt tests and the most highly tolerant were selected for use as male parents in 1962. Six of those selected were from the cross Fuggle × 321 and one from Eastwell Golding × 321. Male 321 is the earliest of the original wilt-tolerant males used.

Since male 15 has proved itself outstandingly successful in diploid crosses, all its available male seedlings are being propagated for wilt testing in 1963. These seedlings are derived from crosses with Eastwell Golding, Hallertau, Saaz and Early Bird, and the latter group should be the most interesting as it may combine earliness with good quality characteristics.

In attempts to produce triploid hops suitable for lager brewing, crosses were made between tetraploid Saaz and two male seedlings from the cross diploid Saaz × male 15. These are in addition to a similar cross made in 1960.

Breeding for resistance to downy mildew was continued. Most of the resistant plants so far discovered have very little resin and work is now aimed at raising plants with a reasonable resin content by crossing resistant males with high resin females such as Northern Brewer and Bullion.

Production of Monoecious Plants

Three families designed to produce a high proportion of tetraploid monoecious plants were raised, and in addition to the seedlings planted out in the Nursery Garden a further group was propagated for family wilt tests at East Malling in 1962. Since all the parents were wilt tolerant, or carried genes for tolerance, a high proportion of tolerant seedlings is expected.

Work was also continued on attempts to induce fertile male flowers on female varieties. Once again treatment of Fuggle with alpha(2-chlorphenylthio)propionic acid (2 PSP) induced the development of male flowers but not of viable pollen. A range of chemicals closely related to 2 PSP which had been synthesized by the chemist, failed to produce similar results.

Grafting female plants on to males appeared to induce some morphological effects similar to those obtained with 2 PSP, and a combination of grafting and 2 PSP treatment is planned for 1962.

Weedicide Trial

For many years field bindweed (*Convolvulus arvensis*) has been a problem in the Nursery Garden. Constant grubbing and replanting of certain rows has reduced the shading effect in summer, which with established hills tends to suppress weed growth, and in these areas the bindweed has been spreading. The inclusion of part of the infested area in the propagation nursery made the problem more acute, and it was therefore decided to attempt some form of chemical weed control.

On 18th July a small section of a propagation row containing cuttings of Fuggle "N" growing one foot apart, was treated with a proprietary weedicide containing M.C.P.B. (40 per cent. active ingredient). This was applied with a watering can at a dilution of 0·25 fluid ounces in one gallon of water, at the rate of one gallon to six square yards. Bindweed was well established and in flower and the hop bines were well up their strings at this time. No special attempt was made to avoid spashing the lower laterals with the weedicide. Apart from some distortion of a few of these lower laterals, no other adverse effect was observed on the hops during the rest of the growing season.

By the end of the summer the control of bindweed appeared complete, and when the setts were lifted in the winter there was a marked absence of bindweed roots in the treated area. The individual weight of the setts from the treated area was very variable, but the average weight showed a slight and significant drop when compared with that from the untreated part of the row.

M.C.P.B. at the same rate was applied during the season to certain rows of mature hills in the Nursery Garden where bindweed was well established. The results were encouraging and no adverse effect on the hops was observed.

An experiment of a more detailed and comprehensive nature, involving the use of weedicides for the control of all weeds in hop propagation rows, is planned for the 1962 season.

FIELD EXPERIMENTATION SECTION
REVIEW OF THE YEAR'S WORK

F. C. Thompson and F. H. Beard

General

The section has continued to assist the Head of the Department in the general management of the commercially grown hops at Wye. An account of the growth of the crop from this aspect is given on page 10.

Mr. Thompson continued to serve as a member of the Hops Working Party of the N.A.A.S. and of the Scientific Commission of European Hop Growers Committee. He represented the Scientific Commission at the meeting of the European Brewery Convention Hops Liaison Committee, held in Dublin in February 1962.

Height of Wirework and Spacing Trial

For the third year, this trial was used to investigate the picking of experimental plots by machine, and the results obtained supported the conclusion reached in previous years, that with machine picking the trend of treatment responses and the variability of the results was essentially the same as with hand picking. This particular investigation is now concluded and a final progress report is given on page 69.

Trial of Golding Cones

Data were recorded for the fourth year from the 23 clones under test. On the basis of information obtained in 1958-60, Early Bird A6, Eastwell Golding A2, Cobbs A9 and Mathon 3/91 had been provisionally selected as giving a seasonal succession of clones of high performance. The 1961 results largely confirmed this provisional choice and arrangements have been made to propagate these four clones for distribution to the Industry. A small stock of each is maintained under wilt-free conditions at Luddington Experimental Horticulture Station where the initial stage of propagation will take place. Release to the Industry will include the A-plus propagation scheme.

Trial of Fuggle Clones

Data were recorded for the second year. Owing to adverse seasonal conditions, it was not possible to dress the three early clones before the later clones, but the strongest bine available was trained.

The early clones were picked on 29th and 30th August; Day's 7/15 maintained the highest yield and Calcutt's 2/6 the highest resin content. The later clones were picked on 4th and 5th September; there were no appreciable differences in yield or resin content among these later clones.

Between the two groups of clones there was no difference in resin content, but the mean yield of the 3 early clones (13·1 cwt. per acre) was well below that of the 8 later clones (18·7 cwt. per acre).

European Brewery Convention: Hops Liaison Committee Variety Trials

This trial was planted in 1960 and yields were first recorded in 1961. Of the six varieties in the trial the German Spalt was grubbed in June 1961 owing to symptoms of virus infection. A fresh supply of clean stock has been obtained and will be quarantined near Wye before replanting is considered.

The remaining five varieties were harvested as follows:

(1) Danish seedling S978: picked on 16th August giving a very light crop.
(2) Fuggle N: picked on 5th September giving 20 cwt. per acre.
(3) Northern Brewer: picked on 11th September giving 18·8 cwt. per acre.
(4) Danish seedling S1478: picked on 14th September giving 16·4 cwt. per acre.
(5) German Hallertau: picked on 15th September giving 18·1 cwt. per acre.

S978 continued to be very susceptible to downy mildew attack, necessitating much cutting-out of infected bines and stripping of infected leaves. This resulted in a severe check to growth. Of the other varieties, Hallertau had the highest incidence of infection, while S1478 proved to be almost as resistant as Fuggle.

S1478 gave the highest resin content of the five varieties, but was only slightly higher than Northern Brewer, although it was selected for trial because of its reputation for outstandingly high resins. Hallertau had the lowest resin content of the varieties tested.

Field Manurial Trials

The two 3^3 NPK trials established at Bodiam, Sussex and Teynham, Kent were continued. A progress report on these trials is given on page 44.

In the Stainsmore trial, Bodiam, the results for the three years 1959-61 indicated that manuring at the $N_2P_1K_1$ levels (8 cwt./acre nitro-chalk; 4 cwt./acre basic slag; $1\frac{1}{2}$ cwt./acre muriate of potash) is satisfactory in this garden, but soil analysis shows that the levels of available nutrients are critical and are tending to fall with the lowest levels of manuring. The trial is thus of particular interest for assessing the levels at which heavier manuring may be justified.

In the Norton West trial, Teynham, it was not possible to harvest the plots in 1961, but the treatment responses were assessed by scoring for vigour of growth and cropping potential. This showed a marked response to high nitrogen, but no benefit from the higher levels of phosphate and potash. Seasonal conditions contributed to the nitrogen response. With phosphate and potash the results confirmed that on a soil very high in available P and K, there is nothing to be gained by heavy manuring.

The Department is also collaborating with Guinness Hop Farms in a complex cultural trial, which incorporates a comparison of a proprietary "organic" manure with straight inorganic fertilizers. Data are not yet available.

The trial in Withersdane Garden, Wye, using Whitbread's Golding Variety (1147), was handicapped by severe downy mildew infection of the rootstocks. Yield records were taken, but it was found that the differences shown were primarily related to variations in intensity of downy mildew attack. In consequence, a systematic replanting of this trial, with clean stock prepared by mist propagation, is being undertaken in 1962 and succeeding years.

A final series of cone samples was taken from the magnesium deficiency observation trial at Beckley, Sussex. Although the test plants showed marked differences in magnesium level by leaf analysis, no differences in cone quality could be detected.

Soil and leaf samples for mineral nutrient analysis, and cone samples for resin analysis, were collected to provide data in support of the above trials. In addition, samples supplied by Dr. Williams, and representative of the different parts of the hop plant at different stages of growth, are being analysed for mineral content.

Statistical Work

The statistical analysis of the results of departmental field

experiments, and of resin analysis and leaf analysis data from the Rosemaund hop manurial trial, has been carried out. Assistance has been given with the design of new field experiments in other sections.

CHEMISTRY SECTION
REVIEW OF THE YEAR'S WORK

J. B. Roberts

Gas Chromatography

Determination of the Cohumulone content of Hop Resins

A satisfactory technique was developed for this analysis (1) and used for the analysis of some varieties of interest to the plant breeding section.

Hop Oil Constituents

An investigation of the chemical constituents of essential oil of hops was begun. The oxygenated fraction of the oil was divided into groups by chemical methods, and the groups examined by gas chromatography. The results indicated the presence of a number of high boiling point non-saponifiable compounds in addition to the previously recognized constituents. Methyl geranate appeared to be the principal ester present in the oil (2).

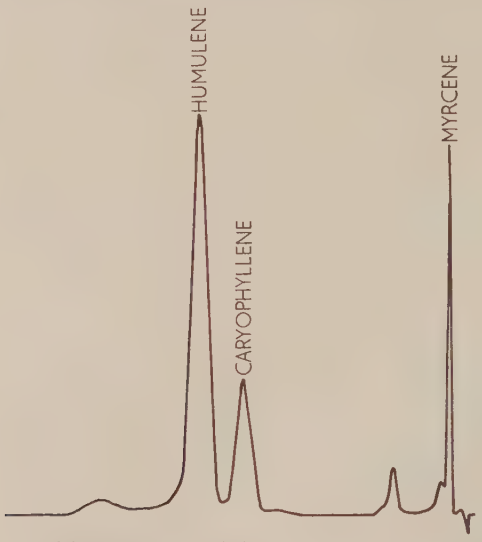
Attention has also been directed at the changes which occur in the essential oil of ripening hops. It was found that in the variety Fuggle N, resins and essential oils are produced simultaneously, but in other varieties resin synthesis can precede the production of essential oil (3) and in this case essential oil synthesis appears to be associated with seed development. It has also been found that seedless hops contain more essential oil than the same variety grown seeded. It appears that the development of the essential oil may be associated with the deposition of storage fats in the ripening seed (4).

In the course of these investigations a series of gas chromatographic analyses was carried out to determine the best conditions for analysis of the hydrocarbon fraction of hop oil. During these analyses it was noticed that the elution sequence of the sesquiterpenes was dependent on the temperature of analysis. A report of this anomalous behaviour has been published (5).

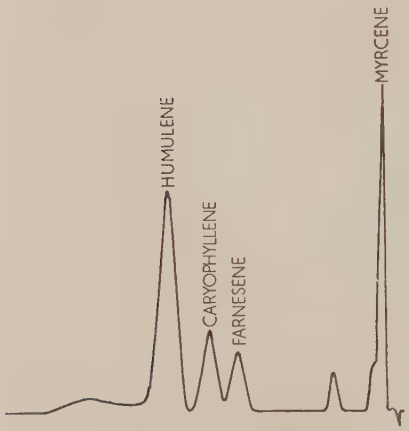
Varietal differences in the major constituents of Essential Oil of Hops

During the year essential oil was distilled from samples of a number of varieties of English and continental hops. These oils were examined by gas chromatography under identical conditions using an Apiezon L column at 175°C. It was found that all the varieties

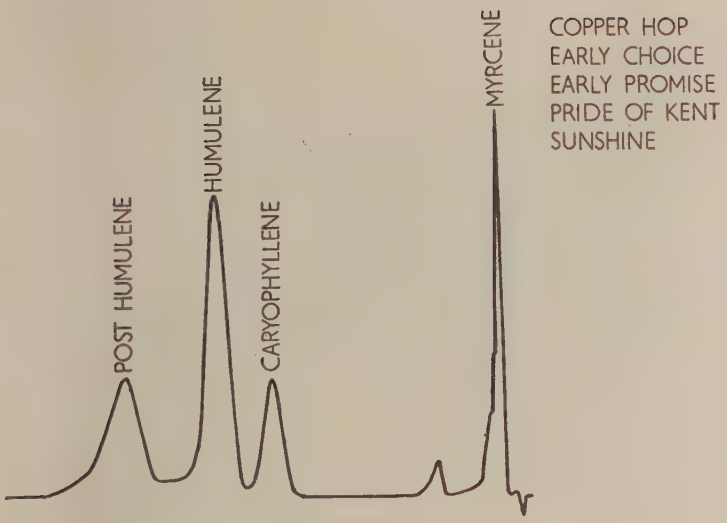
could be placed in one of three groups, on the basis of their major constituents.



(*a*) Hops containing myrcene, caryophyllene and humulene (Fig. 1).



(*b*) Hops containing myrcene, farnesene, caryophyllene, and humulene (Fig. 2).



(*c*) Hops with a high post-humulene content (Fig. 3).

No quantitative measurements were made to group the varieties but it is possible to sub-divide group (*b*) into two parts, that is hops containing more caryophyllene than farnesene, and those containing more farnesene than caryophyllene. Similarly quantitative measurements would no doubt sub-divide the other groups on myrcene contents. However the significance of such measurements is at present difficult to assess, as the myrcene content of an oil is dependent on the history of the sample from which it is derived, and on the age of the oil itself.

The varieties which have been examined are named on the relevant chromatogram.

Growth Substances

The treatment of Bullion hops with gibberellic acid at the burr stage was repeated in collaboration with Dr. R. Stevens of the Brewing Industry Research Foundation. Similar results to those obtained in the 1960 season were recorded (6). A full account of this work has been published (3).

In addition to the above treatment an experiment was carried out in which a group of hop plants (variety Fuggle N) were sprayed

at the time of flower initiation with the following growth substance solutions:

(*a*) Kinetin 10 p.p.m.
(*b*) Gibberellic acid 5 p.p.m.
(*c*) α(2-naphthoxy)propionic acid 50 p.p.m.

A further group were sprayed with the same solutions at the burr stage, and subsequently at weekly intervals until harvest.

Determinations of yield, cone number, resin content, essential oil content and seed content were made in each case.

It was found that spraying with gibberellic acid at the time of flower initiation caused a 70% increase in the number of cones at harvest, but no significant change in yield or resin content of the hops. No other spray had any effect at this time. Of the samples sprayed from the burr stage onwards, it was found, as had previously been shown by Seeley and Wain (7) that α(2-naphthoxy)propionic acid caused initial stimulation of the development of the cones, but this was not maintained, with the result that at harvest there was no significant difference between the sprayed and unsprayed hops.

It is possible however that a combination of these two treatments i.e. gibberellic acid at flower initiation followed by α(2-naphthoxy) propionic acid at the burr stage might give interesting results.

Routine Analyses

During the year approximately 900 resin analyses have been carried out on hop samples in support of research in the department and elsewhere. Analyses of leaf and soil samples for inorganic constituents in support of manurial trials have continued and a series of analyses has been started of the seasonal changes in the mineral constituents of the leaves, laterals, bines and roots of the hop.

Publications

Papers published during the year comprise the first six references listed below.

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(3) ——— and Stevens, R. (1962). The effect of gibberellic acid on the growth of hops. *Ibid.*, 247.
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(6) Stevens, R., Roberts, J. B. and Williams, I. H. (1961). Treatment of hops (*Humulus lupulus* L.) with gibberellic acid. *Ibid.*, *191*, 360.
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ENTOMOLOGY SECTION
REVIEW OF THE YEAR'S WORK

H. S. Darling

Systemic Insecticides and the Control of the Hop Aphis

The replicated insecticide trial on the control of the hop aphis, *Phorodon humuli* Schr., carried out in 1958, 1959 and 1960 (Darling and Beard, 1959; Darling, 1960; Darling, 1961) was repeated for the last time. As in previous years, hops of the variety Petham Golding were used, being planted on the square at 6½ ft. spacing (2 metres) and grown on wirework 16 ft. (4·9 metres) high. Normal umbrella stringing was used with four strings per plant, two bines being trained up each string. The experiment received the routine cultural, fungicidal and manurial management given to the College hop gardens as a whole, and was harvested by hand on 19th September, 1961.

The insecticide treatments were once again as follows:

(1) Derris applied as a high volume spray.
(2) Demeton methyl applied as a soil drench to each hill at 0·25 gm. commercial active ingredient in 120 ml. water per application.
(3) Dimefox applied as a soil drench at the same rate per application as in (2) above.

The derris sprays were applied eight times from 23rd May to 17th August. At each application of derris the other treatments were similarly sprayed with water only. Demeton methyl was applied three times: on 17th May, 31st May and 21st June. Dimefox was applied twice: on 17th May and 21st June. The same plots were used for each treatment as in 1960, and the insecticide applied to each plant was that with which it had been treated throughout its life. There was therefore no possibility of one insecticide interfering with the action of another by carry-over effects in the rootstocks.

The mild weather of March and April encouraged early development of foliage generally and the first winged aphids were observed on the experimental plants by the exceptionally early date of 4th May. Populations then increased slowly (May temperatures were below average with night frosts) and by 10th May winged adults were numerous and nymphs could be found without diffi-

culty on the expanding hop leaves. By 17th May populations were heavy with rapid breeding taking place so that 100 per cent. of the leaves on the experimental plants were infested with nymphs. For the remainder of May and throughout June aphis attack was severe; winged adults continued to arrive in the hops in large numbers and in the absence of adequate control measures, very large infestations developed. During the first half of July the number of winged migrant adults decreased sharply and by the middle of this month the invasion was over for the season. No attack by red spider was observed.

The effects of the insecticidal treatments were assessed at intervals during the summer by examining with a hand lens, random samples of 100 leaves selected from 90-100 plants per treatment. These random samples were selected from leaves physiologically suitable for aphis breeding, i.e. young expanding leaves near growing points and semi-senescent mainstem leaves. Results were expressed as percentage of leaves per treatment showing infestations of late stage nymphs and wingless adults. In view of the slow rate of kill that can occur with systemic insecticides, the presence on a leaf of winged adults or young nymphs was not regarded as indicating an established infestation. The summarized results of aphid counts are tabulated below.

Date	Percentage of leaves with aphis infestations		
	Derris	Demeton methyl	Dimefox
17th May	100	100	100
24th May	98	0	0
31st May	53	0	0
9th June	77	0	0
14th June	3	0	0
21st June	62	5	4
28th June	48	0	0
6th July	47	0	0
26th July	21	0	0

It will be noted that as in previous years, both systemic insecticides give virtually complete aphis control throughout the season. Derris gave sufficient control to permit the plants to develop their normal structure but failed to reduce aphid populations sufficiently to prevent leaf damage. The very low degree of infestation recorded in the derris treatment on 14th June was due to accidental contamination of the spray fluid by residues from routine demeton methyl applications made elsewhere with the same machine. The concentra-

tion of this systemic chemical in the derris spray was very low (not exceeding 1 ounce of the commercial formulation per 100 gallons) but the effect was pronounced. It was also ephemeral and a week later populations had re-established themselves.

At harvesting, random samples of 100 green cones from each treatment were examined carefully with a hand lens. Neither of the systemic insecticide treatments had any aphids in the cones but the derris treatment had 7 per cent. of the cones infested.

The following yields were obtained:

Derris	14·9	cwt.	dried	hops	per	acre
Demeton methyl	17·3	,,	,,	,,	,,	,,
Dimefox	18·1	,,	,,	,,	,,	,,
Least significant difference (P=0·05)	1·9	,,	,,	,,	,,	,,

These results indicate that the difference between moderate and complete aphis control was reflected in a significant yield increase of from 2 to 3 cwt. of dried hops per acre. As in the three previous seasons, the dimefox treatment outyielded demeton methyl but the difference was not significant.

Estimates were made of the number of bushels of green hops required to give one cwt. of dried hops, by the technique introduced in 1960. A standard measure of three full quarts (3·5 litres) was used, 16 such measures being taken at random from each treatment at hop picking. Each measure of hops was first put in a polythene bag and weighed green; it was later transferred to a muslin bag in which it was dried for 12 hours at 120° F with an airspeed of 30 ft. per minute, giving a final moisture content in the normal commercial range of 9 per cent. to 10 per cent. Each measure of hops was weighed after drying and samples were taken for resin analysis and moisture content estimation. From the data obtained from these 48 standard volumes of green hops the following calculated results were obtained:

Derris	85	green	bushels	per	dried	cwt.
Demeton methyl	88	,,	,,	,,	,,	,,
Dimefox	89	,,	,,	,,	,,	,,
Least significant difference (P=0·05)	4·2	,,	,,	,,	,,	,,

These values are appreciably lower than those recorded in 1960 and this decrease is presumably associated with the dry summer of 1961. As in 1960, derris gave the lowest bushel/cwt. ratio of all three treatments, but in 1961 the difference was not quite significant.

Resin analyses of 8 samples from each of the three treatments gave the following average results:

	Alpha acids %	*Beta fraction* %	*Total soft Resins* %
Derris	3·9	7·1	11·0
Demeton methyl	3·7	6·6	10·3
Dimefox	3·8	7·1	10·9

These values are in the range expected for Golding hops under the poor conditions of the 1961 season, and they do not show any significant treatment differences.

This trial is to be discontinued as the results obtained over the four years 1958-61 may be summarized as follows:

Yield of dried hops

Yield data in cwt. of dried hops per acre are set out below:

Treatment	*1958*	*1959*	*1960*	*1961*	*Mean*
Derris	17·7	19·1	9·3	14·9	15·3
Demeton methyl	19·5	20·9	11·9	17·3	17·4
Dimefox	21·2	21·3	13·6	18·1	18·6

The use of systemic insecticides significantly increased the yield by 2 to 3 cwt. dried hops per acre compared with the derris treatment.

In each year of the trial the dimefox-treated hops outyielded the demeton methyl treatment but in no year could the difference be shown to be statistically significant. The mean yield difference between the two treatments over four years was 1·2 cwt. per acre. This yield difference was so consistent that it must be regarded as real. It cannot be accounted for by differences in aphicidal efficiency between the two treatments since both remained virtually aphis-free in all four growing seasons. It is possible that it was due to some non-insecticidal action such as that recorded with systemic insecticides by Wallace (1961) with subterranean clover and by El-Rafie and El-Hennawi (1961) with cotton.

Resin content of the cones

Replicated series of samples of dried cones were analysed each year and the following mean values for the four years were obtained:

Treatment	*Alpha acid*	*Beta fraction*	*Total Soft Resin*
	%	%	%
Derris	5·0	6·0	11·0
Demeton methyl	5·0	5·9	10·9
Dimefox	5·1	6·1	11·2

These results indicate clearly that there were no differences in quality between the treatments as revealed by resin analysis.

Green bushels per dried cwt.

Relatively precise estimates were made in 1960 and 1961 of the number of bushels of green hops required to give one cwt. of dried hops. The mean results are tabulated below:

Treatment	*1960*	*1961*	*Mean*
Derris	94	85	88
Demeton methyl	107	88	98
Dimefox	101	89	95

In 1960 the value for derris was significantly lower than for the two systemic insecticides; in 1961 though the value for derris was again the lowest of the three treatments, the result was not quite statistically significant. The mean values for the two years indicate an order of difference in the bushel/cwt. ratio between the derris and the systemic insecticide treatments which is similar to that suggested by earlier surveys of farm data (Darling, 1958).

While it would appear reasonably certain that the use of systemic insecticides increases the bushel/cwt. ratio, the rapid development of machine picking (in which picking capacity is no longer measured by volume) means that the subject has lost its practical importance.

Observation Trials with New Systemic Insecticides

Small-scale observation trials were carried out with a number of newer systemic insecticides not generally used in hops. These included menazon (triazinyl phosphate), derivatives of demeton methyl, and other compounds still on the secret list of the manufacturers concerned. All these chemicals showed considerable aphicidal activity but none was of sufficient merit to be judged more effective than the systemic insecticides now in commercial use.

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PATHOLOGY SECTION
REVIEW OF THE YEAR'S WORK

J. R. Coley-Smith and F. H. Beard

Hill Dusting and Spraying Trials

The long-term clonal Goldings hill dusting experiment, now in its fifth year, again gave encouraging results. The level of systemic rootstock infection obtained by examination of hills at dressing time rose to 40% of hills in the undusted controls. There was less than half this infection in all three fungicide treatments (see previous reports for details of treatments). Basal spike numbers in general reflected the degree of rootstock infection within the plots, the highest number of basal spikes occurring in the undusted controls.

Bordeaux powder hill dusting trials, in clonal Eastwell Goldings at Wye College, and in Bramlings on a commercial grower's farm, have also begun to yield encouraging results in protecting healthy rootstocks from downy mildew disease. There was again no evidence that long-term hill dusting with Bordeaux powder has any effect on either yield or quality of hops.

A hill spraying trial commenced in 1961 has so far given insufficient results to assess the efficiency of this means of controlling rootstock disease and basal spike numbers.

Downy Mildew Resistance Tests

Two thousand seedlings produced by the Plant Breeding Section were screened for resistance to downy mildew disease. Two hundred of the seedlings were retained and planted in an unsprayed garden for further observations.

A pot-plant method for testing rootstock resistance was investigated. This proved to be too cumbersome for routine testing of large numbers of varieties but may be of use for detailed study of selected varieties such as new seedlings about to undergo farm trials or being released to commercial growers.

Infection of Hop Rootstocks by *Pseudoperonospora humuli*

Inoculation of the base of bines of field plants showed that infection in the lower part of the shoot, leading to rootstock disease, was possible between April and September.

The effect on crop yield of rootstock infection by downy mildew was measured in a number of Golding clones. Plants with infected rootstocks were marked at dressing time and later in the season individual hills were hand harvested. The mean loss of yield associated with rootstock infection was 27·7 per cent. in terms of cwt. dry hops per acre.

Glasshouse Testing of Fungicides Against Downy Mildew Disease

A method has been developed for preliminary screening of fungicides against downy mildew disease. Pot plants were placed on a revolving turntable and were sprayed with a standard volume of fungicide from an atomiser operated at a fixed pressure and at a fixed distance from the plants. The department wishes to thank Professor R. L. Wain for making available the equipment used in this work.

Epidemiology of Hop Downy Mildew

Growth room and glasshouse studies of external factors influencing infection, sporulation and rate of disease development have been carried out. Apparatus at Rothamsted of Dr. J. M. Hirst was used to investigate the effects of wind speed, humidity changes and rainsplash on spore liberation. It is hoped that these studies will prove useful in interpreting field data.

CROP PHYSIOLOGY SECTION

REVIEW OF THE YEAR'S WORK

I. H. Williams

The Storage of Carbohydrate Reserves and Cultural Treatments

Growth analysis and carbohydrate analysis was carried out at weekly intervals of entire, mature plants of the variety Fuggle N growing in the field under standard cultural conditions. Results confirm and amplify the findings of earlier studies with young plants grown in the open in pots (Williams, 1960; Williams, Roberts and Coley-Smith, 1961).

In 1960, young plants of the variety Fuggle N grown from trimmed setts, were stripped of their lower leaves and some were also cut at the banding-in string in early September as for machine picking. Rootstocks from these treatments, and from a control group which had been allowed to grow without stripping or cutting were set out in the field in a small replicated and randomized experiment in 1961. Yields were significantly heavier with the controls. Stripping young plants gave a more severe check in the following year than cutting the bine as for the machine. This experiment suggests strongly that, when replanting, full yielding capacity is likely to be attained more rapidly where stripping is reduced to a minimum. This experiment is discussed in detail on page 59.

Propagation

Soft-wood cuttings rooted under mist were planted out at two week intervals in the field from 13th April to 1st September in 1960. The resulting rootstocks were lifted in the winter and set out in a replicated and randomized trial in the field in 1961, together with 100 normal bedded setts of the same variety (Fuggle N) as controls. At the end of the growing season, yield data was recorded. Soft-wood cuttings planted from mid-April to the end of May in 1960 gave yields in 1961 comparable with the controls planted in that year. Rootstocks from later plantings in 1960 gave smaller yields in 1961 than did the control bedded setts.

Height of Wirework

Random sampling of the varieties Fuggle, Northern Brewer and Bullion was carried out to find out the distribution of cones on individual hills in relation to yield differences due to different heights and spacings. Dry weight yield of cones on 3 ft. lengths up the bines of 96 hills were obtained and results agreed well with overall plot yield data. These results are given in detail on page 75.

Irrigation

The large-scale replicated experiment at Guinness Hop Farms Ltd., Bodiam, was repeated for the fourth year using a new site and mature plants of the variety Fuggle N. The maximum amount of irrigation was 7 in. of water applied during April—August and this treatment gave a significant yield increase of more than 2 cwt. dried hops per acre compared with controls receiving no irrigation.

Dormancy and Environment

The feasibility of obtaining plants in flower for experimental work during the dormant winter period was examined. Soft-wood cuttings of the variety Eastwell Golding and two males were placed in heated glasshouses under two daylengths, 16 hours and continuous light, in October. In late December or early January plants developed flowers. Those under continuous light were a little later than those under a 16 hour daylength.

References

Williams, I. H. (1960). Changes in the carbohydrate balance of the hop (*Humulus lupulus* L.) in relation to the annual growth cycle in young plants. *Rep. Dep. Hop Res. Wye Coll. for 1959*, 98.

———, Roberts, J. B. and Coley-Smith, J. R. (1961). Studies of the dormant phase of the hop (*Humulus lupulus* L.). *Ibid. for 1960*, 48.

ENGINEERING RESEARCH FOR THE HOP CROP

REVIEW OF THE YEAR'S WORK

P. H. Bailey* and M. W. Shea

Most of this work was carried out by the Engineering Division of the National Institute of Agricultural Engineering in close collaboration with Wye College.

Drying

The multipoint recording thermometer was installed in the miniature kilns at Wye. The kilns were used extensively for drying experimental material, and the recorder gave a continuous check on temperatures used.

Picking Machinery

(*a*) Comparison of the results from half-plots of the Height of Wirework experiment picked by hand and by machine were continued on the same lines as in 1960; the results were again analysed by computer at Rothamsted Experimental Station and are discussed in detail on page 69. As in 1960, the yields and resin contents indicated by machine picking were somewhat lower than those indicated by hand picking, but the overall pattern of treatment effects was shown as clearly by machine picking as by hand picking. Coefficients of variation were of the same order for hand and machine picking. The three years' work on this comparison taken together show that while the results obtained with machine picking are not identical with those obtained by hand picking (and there is no uniform correction factor that can be applied to convert results obtained one way to be comparable with those obtained the other) machine picking of experiments is entirely feasible without loss of statistical efficiency. This experiment is now completed.

(*b*) A sampling machine was constructed on the final output elevator of the Wye College picking machine to take a representative sample of one-tenth of the total flow for delivery to the sorting machine, and the sorting machine was itself constructed and tested in a lean-to annexe to the picking machine shed.

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The sampling machine worked satisfactorily from the start, the one-tenth samples from twenty 18-hill plots having a standard deviation, in terms of weight, of 1·4 per cent. of the sample or 0·14 per cent. of the whole plot. The sorting machine worked reasonably well except that it was unable to differentiate between petal and small pieces of leaf; experiments were made on sorting these components by aspiration, but it was not possible to obtain a clear-cut separation with a vertical draught. Some measurements on absorption and reflection of monochromatic light by leaf and petal were made with the object of determining the feasibility of a colour separation method.

(*c*) The test of the Rotobank machine picking Bullion was repeated, working on a continuous flow basis; the main results have not yet been evaluated. Following from the 1960 result that only a small proportion of the total leaf and stem was removed at the final visual inspection stage, a trial was made of the effect on valuation of the work of the hand sorters and of the setting of the petal separating belt. Replicate samples were drawn from pokes of hops picked with the hand sorters working and petal included and rejected, and with no hand sorters but petal included. Valuations obtained from two sources both showed a significant effect from machine setting but no significant difference from hand sorting. The value of the final inspection and hand sorting is a complex issue and the result obtained is considered of sufficient interest to warrant the planning of more elaborate experiments in future.

Hop Wirework

(*a*) *Hop Wire Tensions*. The tensometer recorders were again operated from March to September in the Height of Wirework experiment, with similar results to those obtained previously. After overhaul, the tensometers were moved to anchor wires in $6\frac{1}{2}$ and $7\frac{1}{2}$ ft. spacing, in which anchor wire tensions are expected to be higher than in the 9 ft. spacing where the tensometers were previously situated, as there are two rows of hops to an anchor instead of one.

(*b*) *Wirework failures*. A very satisfactory response was obtained to the questionnaire sent out by the Hops Marketing Board. Approximately 80 per cent. of growers returned the initial slips asking if wirework failures had occurred in the years 1958-1960, and over 100 questionnaire forms were completed representing a total of approximately 1,000 acres involved in wirework failure (not

necessarily completely collapsed) over the three years. On the basis of the present survey the average grower might expect a wirework failure about once in 23 years, which would, typically, involve about 9 statute acres of which half would be completely collapsed; it is clear, however, that many of the failures occurred in defective wirework and therefore with good maintenance the average risk would be reduced. Detailed analysis of the survey is proceeding.

(*c*) *Corrosion by copper sprays*. The Hops Marketing Board have circulated a further brief questionnaire to assess the magnitude of the problem.

A TECHNIQUE FOR TESTING HOP VARIETIES FOR DIMEFOX SENSITIVITY

R. F. Farrar

Summary

The development of a simple method of testing new varieties of hop for sensitivity to dimefox is described.

Small pot plants raised from mist-propagated material, when treated with dimefox at a reduced rate, react in a comparable manner to mature hills of the same variety treated normally in the field.

The test proved successful in the glasshouse, in the open and at different times during the season.

The value of the test at Wye, in the variety selection process, is discussed and it is suggested that the technique, with slight modification, may be employed to test the phytotoxicity of other chemicals that may in the future be used in hop production.

Introduction

The susceptibility of certain hop varieties to damage from the soil-applied systemic insecticide dimefox (bis-dimethylamino-fluorophosphine oxide) was first recorded at Wye in 1955, (Darling and Derbyshire, 1956; Neve and Farrar 1956). Tests carried out in 1956 showed that mature hills of susceptible varieties could be killed by the normal commercial dose of 0·5 to 0·6 gm. active ingredient applied in four fluid ounces (114 ml.) of water to each plant (Darling, 1957). It appeared that the existing commercial varieties were able to tolerate the systemic action of dimefox with little or no ill effects, whereas certain new seedling varieties were seriously affected and in some cases killed.

Symptoms generally developed in susceptible hop varieties within 48 hours of treatment with dimefox. The edges of affected leaves curled upwards and became desiccated. Fully expanded leaves which were still fresh and green (i.e. about mid-way up the bine), were the first to be affected. In very susceptible varieties, damage continued to spread in affected leaves until the laminae became dark and sear and whole leaves eventually died. This continued damage spread both up and down the bine until the whole plant was killed; the complete process taking no more than a month with a mature hill. Moderately susceptible varieties were sufficiently damaged for the crop to be seriously reduced, although the hills survived.

The excellent aphis control afforded by the use of dimefox naturally led to its wide use by hop growers, and it was evident that any new hop variety would have to be tested for possible reaction to the insecticide before being generally released.

Owing to the large number of new varieties being handled at Wye, the problem was to devise a rapid and simple test which would give an indication of reaction under commercial conditions, but at the same time avoid the risk of serious damage to the small clone available in the early stage of work on any one variety. This meant that the test could not be conveniently carried out on mature hills; a pot test using mist-propagated material appeared to be the most satisfactory alternative provided that it could be shown that pot plants would react in a similar manner to plants in the field.

1959 Test

The following four varieties of known field reaction to dimefox were selected:

Eastwell Golding	Not susceptible.
Fuggle N	Slightly susceptible under adverse soil conditions.
W/E 752	Moderately susceptible.
W/E 664	Very susceptible.

Softwood cuttings of these varieties were placed in a mist bench on 4th July. By 16th September, 20 plants of each variety had been potted into five-inch clay pots and growth had reached the top of three-foot canes. During that evening each treated plant received two fluid ounces of half-strength dimefox solution, poured on to the base of the bines. This dose of approximately 0·14 gm. active ingredient per plant represented a quarter the rate for a mature hill.

One pot each of three of the varieties was available as an untreated control. All the pots were standing in an unheated glasshouse.

Symptoms began to appear after 48 hours, and by 21st September the record was as follows:

Eastwell Golding	Slight edge effect on two plants.
Fuggle N	General edge effect.
W/E 752	Fairly severe damage.
W/E 664	Very severe damage.

These symptoms subsequently increased until W/E 752 and W/E 664 were killed and Fuggle N showed damage far in excess of any recorded in the field. Only Eastwell Golding maintained active growth, with slight edge symptoms.

It was clear that the dose rate was too high and a second trial was planned for 1960.

1960 Test

The same four varieties were used, and mist propagated material was raised in the same manner as in the 1959 test, with the exception that only one bine per plant was allowed to grow. Pots were set out in the open in four groups, with five plants of each variety in each group.

On 2nd August, the majority of bines had reached three feet in height and treatment with dimefox was applied as follows:

Group 1. 2 fluid ounces at $\frac{1}{4}$ commercial strength per pot (approximately 0·07 gm. active ingredient).

Group 2. 2 fluid ounces at $\frac{1}{6}$ commercial strength per pot (approximately 0·05 gm. active ingredient).

Group 3. 2 fluid ounces at $\frac{1}{8}$ commercial strength per pot (approximately 0·037 gm. active ingredient).

Group 4. Untreated control.

By 5th August the above ground growth of W/E 664 was apparently dead in all treated groups. The W/E 752 plants showed severe symptoms on 4th and 5th August, and all but one, in Group 3, succumbed by 15th August. Fuggle N and Eastwell Golding showed slight symptoms in all treated groups but the plants later recovered. There were of course no symptoms in the untreated controls but the plants were of value in that they showed the normal end of season deterioration of leaves under pot conditions, and therefore confusion with the true phytotoxic effect of the dimefox was avoided.

The pots were allowed to remain *in situ* throughout the winter, and on 14th April, 1961 all the plants were knocked out and examined. The controls and the treated Eastwell Golding and Fuggle plants were alive and growing away normally. With the exception of one plant of W/E 752 in Group 3, which was just alive, *all the other treated plants were completely dead.*

From these results it was concluded that a two fluid ounce dose of $\frac{1}{6}$ commercial strength dimefox (equivalent to $\frac{1}{12}$ commercial rate), applied in the manner described, would give a satisfactory indication of the reaction to dimefox of a variety in the field. Five

plants of any one variety appeared to provide adequate replication for this test, which has been adopted as a standard technique at Wye.

1961 Tests

Seven male varieties used extensively in the breeding programme at Wye were tested during 1961. Plants of Eastwell Golding and Fuggle N were available as controls.

The technique described above was used, and its reliability further tested by treating three separate batches of plants during the season. The test material was raised from stock plants grown under glass and it was possible to carry out the first treatment on 6th June. Seven days later, one of the males was completely dead; the Fuggle N control was showing slight edge symptoms but the plants soon recovered. The other males were undamaged.

The second and third treatments were made on 10th July and 4th September, and the reaction of the treated plants on both occasions was almost identical to the first treatment. There were very slight variations in response but these were too small to influence the outcome of the test. Of the seven males tested, only one proved to be susceptible to dimefox, and that very markedly so.

Conclusions

While dimefox continues to be widely used, new varieties being selected at Wye will be tested in the manner described as soon as real commercial promise is apparent. The simplicity of the technique means that the test can be carried out whenever softwood (vegetative) material is available, and the result obtained in less than two months, without jeopardizing valuable mature hills. Susceptibility of a variety to damage from dimefox may well be a deciding factor in the selection process where other varietal differences are small.

Should new chemical compounds come into use in hop production which prove to have a similar varietal phytotoxicity, the technique should be capable of modification to cover this eventuality.

The possibility that hop varieties may react in the field in a different way to that in a pot is considered to be slight, but it is intended to follow the pot test by a field test wherever practicable.

References

Darling, H. S. and Derbyshire, D. M. (1956). Pathology Section: review of the year's work. *Rep. Dep. Hop Res. Wye Coll. for 1955*, 43.

Neve, R. A. and Farrar, R. F. (1956). Plant Breeding Section: review of the year's work. *Ibid.*, 22.

Darling, H. S. (1957). Review of research. *Ibid. for 1956*, 5.

HOP MANURIAL TRIALS

A PROGRESS REPORT FOR THE PERIOD 1958-61

F. C. Thompson

Summary

A series of NPK trials has been laid down, in East Kent and East Sussex, to find the most suitable levels of manuring for hops in established gardens of medium to high fertility. The results to date indicate that, under these conditions, satisfactory crops of hops can be grown with much less manure than it has been traditional practice to give in the past.

Introduction

From the results of a long term manurial trial on hops, Thompson (1960) showed that with a newly planted hop garden, on soil of low fertility, large yield responses were obtained initially from heavy applications of phosphate and potash fertilizers. When, however, the available phosphorus and potassium in the soil had been built-up to very high levels, heavy applications of phosphate and potash fertilizers were of little or no benefit to the crop.

With the object of getting more precise information on the most suitable levels of manuring in established hop gardens of medium to high fertility, a series of NPK trials was laid down in 1958 and 1959. At the time, land was not available at Wye for such trials, but through the courtesy of Guinness Hop Farms Ltd., sites were found on their farms at Teynham in East Kent and Bodiam, Sussex. The Teynham trial was sited in Norton West Garden, the variety being Bullion planted at 8 × 8 ft. square. At Bodiam the trial started in 1958 was sited in Shinmore Garden, the variety being Keyworth's Midseason (OR55) planted at 7 × 7 ft. square; a second trial, started in 1959, was located in Stainsmore Garden, where the variety is Fuggle, planted at 7 × 7 ft. square. The Shinmore trial was discontinued after the 1959 season, as by then severe downy mildew infection of the rootstocks had developed, necessitating much replanting in the trial area and consequent uneven growth in the experimental plots. The other two trials are being continued.

Experimental Design

In all three trials the layout adopted was a standard three level NPK factorial design; in the Stainsmore trial at Bodiam an additional three plots were included, to test a proprietary organic hop manure.

As labour for plot picking and yield recording was limited, plot size had to be kept to the minimum. Each plot consisted of five plants (hills) this number being based on the work of Keller (1949) in the U.S.A., who found, from uniformity trial data, that this was the smallest unit which could be used to give reliable results. The plots were separated from each other by single guard rows.

Materials and Methods

Manurial treatments

Although the aim was to test comparable rates of N, P and K manuring at each centre, the treatments tested differed in detail and are given in full in the individual reports on each trial.

Crop records and resin analysis

The plots were harvested in September and green weights recorded. At the same time samples were taken from each plot for dry matter determinations. These samples were kiln dried and were subsequently used for resin analyses.

Soil analysis

Soil samples were taken from all plots each year in mid-winter, and analysed for available P and K using a quick extraction technique with Morgan's reagent. Determinations were also made of total nitrogen (Kjeldahl) and organic carbon (Walkley-Black method).

Leaf analysis

Leaf samples were taken annually, selecting fully expanded but not senescent leaves. Sampling was carried out at the end of June or beginning of July. After removal of the petioles, the laminae were dried at 100° C and analysed for total N, P, K, Mg and Ca.

Norton West Garden, Teynham

Soil

The soil in this garden is of brickearth type overlying chalk and the pH tends to increase with depth, ranging from 6·9 to 7·2 in the 0-6 ins. layer and from 7·5 to 8·0 in the 6-12 in. layer.

Manurial Treatments

The whole experimental area received an annual dressing of 15 tons per acre dung.

The NPK treatments applied in 1958 and 1959 were as follows:

Nitrogen as sulphate of ammonia at 3, 6 and 9 cwt. per acre (approx. 70, 140 and 210 lb. per acre N)—treatments N1, N2 and N3. With each treatment half the dressing was applied in March, and half in early June.

Phosphate as superphosphate at 3, 6 and 9 cwt. per acre (approx. 60, 120 and 180 lb. per acre P_2O_5)—treatments P1, P2 and P3, applied in March.

Potash as muriate of potash at $1\frac{1}{2}$, 3 and $4\frac{1}{2}$ cwt. per acre (approx. 100, 200 and 300 lb. per acre K_2O)—treatments K1, K2 and K3, applied in March.

For 1960 and 1961, the P1, P2, and P3 treatments were revised to NIL, 3 cwt. and 6 cwt. per acre superphosphate respectively, as the results obtained in 1958 and 1959 had shown no gain in yield from high phosphate manuring.

Results

Yield

The mean data for the three years 1958-1960 are given in Table 1, and it may be seen that response to manuring varied considerably with season, but that over the three year period there was nothing to be gained by heavy manuring.

Table 1

Effect of Manurial Treatments on the Yield of Dry Hops, in cwt. per acre

Year	Treatment means									Yearly mean
	N1	N2	N3	P1	P2	P3	K1	K2	K3	
1958	27·0	27·0	23·9	27·2	25·7	25·0	25·4	25·9	26·6	26·0
1959	25·2	24·7	24·1	26·2	22·5	25·4	25·4	25·1	23·7	24·7
1960	27·1	28·5	28·3	28·6	27·0	28·3	27·3	27·5	29·1	28·0
Mean	26·4	26·7	25·4	27·3	25·1	26·2	26·0	26·2	26·5	26·2

In 1961 it was not possible to harvest the trial, but the response to the different treatments was assessed by scoring each plot for vigour of growth and potential crop. On this basis there was evidence of response to high nitrogen, but with phosphate and potash the scoring supported the overall results of the previous three years in showing no benefit from heavy applications of these fertilizers.

Soil analyses

Mean data for the 1957 sampling, and the three year mean results for the period 1958-60, are given in Table 2.

TABLE 2

EFFECT OF MANURIAL TREATMENTS ON THE TOTAL NITROGEN AND AVAILABLE PHOSPHORUS AND POTASSIUM CONTENTS OF THE SOIL

Year of sampling	Treatment means								
	Total N %			Avail. P p.p.m.			Avail. K p.p.m.		
	N1	N2	N3	P1	P2	P3	K1	K2	K3
1957	0·36	0·34	0·36	31·8	30·6	32·1	201	184	197
1958-60	0·34	0·34	0·35	27·2	26·9	29·4	155	163	170

The 1957 sampling was carried out before applying the fertilizer treatments and the results show that the nitrogen level was satisfactory and the contents of available phosphorus and potassium extremely high. Subsequently these levels have fallen, even at the highest levels of NPK manuring.

Leaf analyses

Mean data for the three year period 1958-60 are given in Table 3.

TABLE 3

EFFECT OF MANURIAL TREATMENTS ON THE CHEMICAL COMPOSITION OF HOP LEAVES. MEAN VALUES FOR THE PERIOD 1958-60, EXPRESSED AS A PERCENTAGE OF DRY MATTER

Element	Treatment means									Overall mean
	N1	N2	N3	P1	P2	P3	K1	K2	K3	
N	3·96	4·02	4·09	4·08	3·97	4·03	4·04	4·00	4·03	4·02
P	0·42	0·42	0·41	0·42	0·41	0·41	0·42	0·40	0·41	0·41
K	2·94	2·98	3·01	3·02	2·95	2·93	3·01	2·95	2·96	2·97
Mg	0·33	0·33	0·34	0·33	0·33	0·34	0·33	0·33	0·34	0·33
Ca	2·72	2·70	2·78	2·76	2·73	2·71	2·69	2·72	2·79	2·73

Leaf analysis shows that the plants have absorbed an ample supply of mineral nutrients with all treatments, and there are no appreciable differences in leaf mineral content due to the different treatments.

Discussion

For some years prior to the commencement of the trial, this garden had been heavily manured on traditional lines, and had achieved satisfactory levels of soil organic matter and total nitrogen. Both of these soil constituents have subsequently shown a slight fall, and it is clear that even the relatively heavy annual application of 15 tons per acre dung is not adequate to maintain soil organic matter and still heavier dressings are needed periodically. Yield response to inorganic nitrogen manuring has varied with season but, in general, the best results have been obtained with 6 cwt. per acre sulphate of ammonia.

The heavy manuring given to the garden had also resulted in the build-up of extremely high levels of available phosphorus and potassium, but with the fertilizer treatments adopted in the trial these levels are now falling, even at the highest rates of application of phosphate and potash. Nevertheless, over the four year period of the trial, there is no evidence that yield has suffered when phosphate manuring has been reduced to 3 cwt. per acre superphosphate, or omitted altogether. With potash, more conflicting results have been obtained, but again there is no consistent evidence of reduced yield at the lowest level of potash manuring adopted.

Shinmore Garden, Bodiam

Soil

In this garden the soil is brickearth material derived from the Tunbridge Wells Sand with a pH of about 7·5 in the top soil (0-6 in.) decreasing to 7·0 in the 6-12 in. layer.

Manurial Treatments

As in Norton West, the whole experimental area received an annual dressing of 15 tons per acre dung.

The treatments applied in the two years of the trial (1958 and 1959) were as follows:

Nitrogen as Nitro-chalk at 4, 8 and 12 cwt. per acre (approx. 70, 140 and 210 lb. per acre N)—treatments N1, N2 and N3. With each treatment half the dressing was applied in March, and half in early June.

Phosphate as basic slag at 4, 8 and 12 cwt. per acre (approx. 60, 120 and 180 lb. per acre P_2O_5)—treatments P1, P2 and P3, applied in March.

Potash as muriate of potash at $1\frac{1}{2}$, 3 and $4\frac{1}{2}$ cwt. per acre (approx. 100, 200 and 300 lb. per acre K_2O)—treatments K1, K2 and K3 applied in March.

Results

Yield

The mean data for the two year period of the trial, 1958-59, are given in Table 4. The results show a more pronounced response to high nitrogen than in the Norton West, probably due to the much lower level of soil nitrogen found in Shinmore. With phosphate and potash the responses to the different treatments have been inconsistent. In particular, the anomalous depression in yield found at the P2 level in both years, must be regarded as a site effect, the P2 treatments being located by chance on inherently low yielding plots.

Table 4

Effect of Manurial Treatments on the Yield of Dry Hops in cwt. per acre

Year	Treatment means									Yearly mean
	N1	N2	N3	P1	P2	P3	K1	K2	K3	
1958	14·6	14·1	15·4	15·0	13·4	15·7	14·9	13·8	15·4	14·7
1959	16·2	18·0	18·2	17·2	16·4	18·7	17·1	18·4	16·9	17·5
Mean	15·4	16·1	16·8	16·1	14·9	17·2	16·0	16·1	16·2	16·1

Soil analyses

Mean data for the 1957 sampling, and the two year mean results for the period 1958-59, are given in Table 5.

Table 5

Effect of Manurial Treatments on the total Nitrogen and Available Phosphorus and Potassium Contents of the soil

Year of sampling	Treatment means								
	Total N %			Avail. P p.p.m.			Avail. K p.p.m.		
	N1	N2	N3	P1	P2	P3	K1	K2	K3
1957	0·17	0·17	0·17	10·7	11·0	11·4	80	84	78
1958-59	0·17	0·16	0·17	10·1	11·3	12·7	57	64	71

Sampling in 1957 was carried out before applying the fertilizer treatments and the results show that soil nitrogen was then at a low

level, but both available phosphorus and potassium were in the very high grade. Subsequently the levels of both soil nitrogen and available phosphorus have been little affected by the differential nitrogen and phosphate manuring adopted in the trial. With available potassium, however, the rates of potash manuring tested have not succeeded in maintaining the initial soil level, even at the highest rate of application.

Leaf analyses

Mean data for the two year period 1958-59, are given in Table 6.

TABLE 6

EFFECT OF MANURIAL TREATMENTS ON THE CHEMICAL COMPOSITION OF HOP LEAVES. MEAN VALUES FOR THE PERIOD 1958-59, EXPRESSED AS A PERCENTAGE OF DRY MATTER

Element	Treatment means									Overall mean
	N1	N2	N3	P1	P2	P3	K1	K2	K3	
N	4·70	4·60	4·58	4·65	4·59	4·65	4·68	4·62	4·59	4·63
P	0·37	0·35	0·36	0·37	0·36	0·36	0·35	0·37	0·36	0·36
K	2·49	2·43	2·41	2·49	2·37	2·48	2·37	2·48	2·48	2·44
Mg	0·34	0·35	0·35	0·33	0·35	0·35	0·35	0·35	0·34	0·35
Ca	1·35	1·41	1·44	1·32	1·48	1·39	1·41	1·35	1·44	1·40

As in Norton West, leaf analysis shows that the plants have absorbed an ample supply of the main mineral nutrients, with all treatments. There has been some increase in leaf potassium at the higher levels of potash manuring.

DISCUSSION

This garden was first planted to hops in 1951 and at that time the soil was in a very low state of fertility. By 1957, soil organic matter and total nitrogen were still low but, as a result of heavy annual applications of inorganic phosphate and potash fertilizers, the levels of available phosphorus and potassium in the soil had been built-up to the very high grade.

Over the period of the trial, differential nitrogen manuring had little effect on the level of soil nitrogen, which has remained low, and high nitrogen manuring has increased yield. The different phosphate treatments have also had little effect on the level of available phosphorus, but with potash, even the highest rate of application has not succeeded in maintaining the initial level of available potassium. Nevertheless, there is no consistent evidence

of any gain in yield from the higher rates of either phosphate or potash manuring tested, and it would seem that when soil available phosphorus and potassium are in the high to very high range, applications of 3 cwt. per acre superphosphate and 1½ cwt. per acre muriate of potash, in conjunction with a basal dressing of dung, are ample to maintain yield. Leaf analysis data lend support to this conclusion.

Stainsmore Garden, Bodiam

Soil

As in Shinmore, the soil in this garden is brickearth material derived from the Tunbridge Wells Sand. This soil is rather more acid, however, ranging from about pH 6·7 in the top 6 in. to 6·0 in the 6-12 in. depth.

Manurial Treatments

The basal dressing of dung and the NPK treatments applied were the same as in the Shinmore trial, but in Stainsmore three additional plots receiving a proprietary organic manure, were located at random in the trial area.

Results

Yield

The mean data for the three years 1959-61 are given in Table 7 and it will be seen that while treatment responses have varied with season, over the three year period of the experiment there has been little benefit from the higher levels of NPK manuring tested.

Table 7

Effect of Manurial Treatments on the Yield of Dry Hops in cwt. per acre

Year	Treatment means									Yearly mean
	N1	N2	N3	P1	P2	P3	K1	K2	K3	
1959	18·4	18·4	18·9	18·5	18·4	18·8	18·0	19·2	18·5	18·6
1960	24·3	24·5	24·7	24·7	24·4	24·5	25·1	24·0	24·5	24·5
1961	11·6	13·3	11·9	11·8	12·5	12·5	12·3	13·9	11·6	12·3
Mean	18·1	18·7	18·5	18·3	18·4	18·6	18·5	18·7	18·2	18·5

Soil analyses

Mean data for the 1958 sampling and the two year mean results for the period 1959-60 are given in Table 8.

TABLE 8

EFFECT OF MANURIAL TREATMENTS ON THE TOTAL NITROGEN AND AVAILABLE PHOSPHORUS AND POTASSIUM CONTENTS OF THE SOIL

Year of sampling	Treatment means								
	Total N %			Avail. P p.p.m.			Avail. K p.p.m.		
	N1	N2	N3	P1	P2	P3	K1	K2	K3
1958	0·23	0·23	0·22	4·5	4·3	4·3	42	44	46
1959-60	0·21	0·21	0·21	3·2	4·7	5·2	39	45	56

In this garden, the 1958 sampling was made before applying the fertilizer treatments, and the results show that soil nitrogen was then at a moderate level, and available phosphorus and potassium in the high and medium-high grades respectively. Subsequently soil nitrogen has tended to fall at all levels of nitrogen manuring, as have available phosphorus and potassium with the P1 and K1 treatments. The latter nutrients have increased, however, with the P3 and K3 treatments.

Leaf analyses

Mean data for the two year period 1959-60 are given in Table 9.

TABLE 9

EFFECT OF MANURIAL TREATMENTS ON THE CHEMICAL COMPOSITION OF HOP LEAVES. MEAN VALUES FOR THE PERIOD 1959-60, EXPRESSED AS A PERCENTAGE OF DRY HOPS

Element	Treatment means									Overall mean
	N1	N2	N3	P1	P2	P3	K1	K2	K3	
N	4·58	4·60	4·62	4·55	4·64	4·61	4·55	4·63	4·62	4·60
P	0·38	0·39	0·38	0·38	0·39	0·38	0·38	0·38	0·38	0·38
K	2·58	2·57	2·53	2·65	2·51	2·54	2·44	2·61	2·65	2·56
Mg	0·38	0·41	0·43	0·41	0·42	0·39	0·40	0·40	0·43	0·41
Ca	2·00	1·96	2·02	1·89	2·04	2·05	1·97	1·94	2·06	1·99

The results show a similar pattern to those found in Shinmore, and there is a similar increase in leaf potassium at the higher levels of potash manuring.

Discussion

Stainsmore garden is comparable to Shinmore, in that it was first planted to hops in 1951, and at that time the soil was in a low state of fertility. At the commencement of the trial, in 1958, the soil nitrogen content was, however, somewhat greater than in Shinmore, but the levels of available phosphorus and potassium were appreciably lower, being in the high and medium high categories respectively.

Subsequently the content of soil nitrogen has fallen slightly, with all treatments, as have the levels of available phosphorus and potassium on the plots receiving the lowest rates of phosphate and potash manuring. With the heaviest applications of phosphate and potash, however, available phosphorus and potassium have risen.

In spite of the relatively low levels of soil N, P and K found in this trial, yield response to differential NPK manuring has been inconsistent and, with one or two exceptions, of little consequence. On average, however, it may be said that that medium levels of nitrogen and potash have given the best results, but with phosphate the higher rates of application tested could not be justified at the present level of soil available phosphorus.

Resin Analysis

The results for all three trials are summarized in Table 10 and show that, in general, differential manuring has had no marked influence on resin content. The most consistent effect has been the depression in both total soft resins and alpha acids with high nitrogen manuring in the Norton West trial, where the level of soil nitrogen is relatively high.

Table 10

Effect of Manurial Treatments on the Resin Content of Hop Cones. Mean Values Expressed as Percentage of Dry Matter

Trial	Resins	Treatment means									
		N1	N2	N3	P1	P2	P3	K1	K2	K3	Mean
Norton West 1958-60	Total soft resins	16.5	16.2	15.9	16.5	16.1	16.0	16.7	15.7	16.2	16.2
	Alpha acids	7.3	7.1	7.0	7.2	7.0	7.2	7.2	7.2	7.0	7.1
Shinmore 1958-59	Total soft resins	11.7	12.4	11.9	11.9	12.0	12.1	11.9	12.1	12.0	12.0
	Alpha acids	5.6	5.9	5.5	5.8	5.7	5.5	5.8	5.7	5.6	5.7
Stainsmore 1959-61	Total soft resins	11.6	11.4	11.4	11.2	11.4	11.8	11.5	11.5	11.5	11.5
	Alpha acids	4.7	4.7	4.9	4.8	4.8	4.9	4.8	4.8	4.7	4.8

Trial With an Organic Hop Manure

Manurial Treatments

As stated above, in the Stainsmore trial at Bodiam an additional three plots were included to test a proprietary organic hop manurial treatment. This consisted of an early hop manure applied in spring, at the recommended rate of 15 cwt. per acre, at the same time as the inorganic NPK treatments given to the main trial. This was followed by an application of a late hop manure, in early June, at the recommended rate of 10 cwt. per acre, at the time of the final nitrogen application to the NPK plots.

The total amount of N, P and K applied in the combined applications was approximately equivalent to 5 cwt. per acre sulphate of ammonia, 23 cwt. per acre superphosphate and 3 cwt. per acre muriate of potash. In other words similar to the N2 and K2 treatments in the NPK part of the trial, but supplying more than twice as much phosphate as the highest (P3) phosphate treatment.

The organic manure plots received the same basal dressing of dung as the inorganic plots.

Results and Discussion

Table 11

Comparison of the Effect of Inorganic Fertilizers and an Organic Manurial Treatment, on the Yield and Resin Content of Dry Hops, and on the Chemical Composition of Soil and of Hop Leaves. Mean Values for the Three Year Period 1959-61 (Yield and Resin Content) and for the two year Period 1959-60 (Soil and Leaf data)

Data recorded	Inorganic treatment	Organic treatment
Yield cwt./acre	18·5	19·2
Total soft resins %	11·5	11·5
Alpha acids %	4·8	4·8
Soil organic carbon % ..	1·76	1·78
Soil total N %	0·20	0·20
Available P p.p.m.	4·4	3·0
Available K p.p.m. ..	47	48
Leaf N % of d.m. ..	4·41	4·43
Leaf P % of d.m.	0·38	0·40
Leaf K % of d.m.	2·57	2·58

A summary of the results obtained to date is given in Table 11, from which it may be seen that the mean yield with the organic

treatment is slightly higher than that obtained with the inorganic treatment. It should be pointed out, however, that this small difference is non-significant, and that over the period of the trial there have been wide differences in yield between the three plots receiving the organic manure.

The remaining data show remarkably close agreement, with the exception of soil available phosphorus, which has actually decreased on the plots receiving the organic treatment. Although the organic manures applied have a very high content of total phosphate, much of this is in a form insoluble in water and as such likely to be only slowly released. In consequence, it may be some time before the level of soil available phosphorus rises.

General Discussion and Conclusions

Under English conditions, a good crop of machine picked hops removes, per acre, approximately 120 lb. N, 40 lb. P_2O_5 and 120 lb. K_2O, or, in terms of fertilizers, some 5 cwt. sulphate of ammonia, 2 cwt. superphosphate and $1\frac{3}{4}$ cwt. muriate of potash. These amounts of phosphate and potash are supplied by a 15 ton per acre dressing of dung, of average composition, which also supplies the equivalent of 2 cwt. sulphate of ammonia, so that the plants' NPK requirements should be met by supplementing the dung with 3 cwt. sulphate of ammonia. With deep soils, of good texture and drainage, built up to a high state of fertility, there is little doubt that such a simple scheme of manuring could be satisfactory for some years. The assessment of soil fertility is, however, a complex problem, and various factors must be taken into account in deciding on the manuring to be given to any particular hop garden.

Important among these factors is the content of soil nutrients which are available to the plant. With nitrogen, there is as yet no satisfactory laboratory test for availability, but the results from the present series of trials suggest that, with hops, the total soil nitrogen may serve as a rough guide to nitrogen response. Thus, where the total soil nitrogen is relatively high, as in Norton West, increasing the nitrogen application from 140 lb. to 210 lb. per acre N, has depressed yield *in certain seasons*, but has had the reverse effect in Shinmore where the total soil nitrogen is half that found in Norton West. Nitrogen response is, however, much influenced by seasonal conditions and nitrogen manuring must, to some extent, be related to the current season's growth. With a 15 ton per acre dressing of

dung, a further 140 lb. per acre N, as 6 cwt. per acre sulphate of ammonia or its equivalent, has been found to be a safe recommendation for hops, and the results from the present trials, in general support this conclusion.

In the case of available phosphorus and potassium, quick tests have been developed which can differentiate between soils containing either a deficiency or an excess of these available nutrients. The response of the hop plant to phosphate and potash manuring, under this extreme condition, has been studied (Thompson, 1960) and as might be expected, under deficiency conditions good responses were obtained to heavy manuring. When, however, the level of available phosphorus was raised above the very high grade, it was found that phosphate fertilizer could be omitted for some years, where dung was used, without lowering crop yield. Complete omission of potash fertilizers was not tested, but when available potassium was very high, heavy potash manuring depressed yield. These findings were contrary to traditional practice, which favoured continual heavy manuring of hops, irrespective of differing soil requirements.

In the present trials, the soil in Norton West contains similar extremely high levels of available phosphorus and potassium, and the results obtained have confirmed the earlier findings with regard to phosphate manuring, where dung is used. With potash, the rate tested has not on average depressed yield, but there has been nothing to be gained by applying more than 100 lb. per acre K_2O.

In Shinmore and Stainsmore gardens, where the soils range from high to very high in available phosphorus, and from medium-high to very high in available potassium, there has been no consistent evidence that manuring at rates above 60 lb. per acre P_2O_5 and 100 lb. per acre K_2O respectively, has benefited the crop. While these quantities of phosphate and potash, when combined with a 15 ton per acre dressing of dung, more than compensate for those removed by the crop, in practice soil fixation reduces the amounts which can be utilized by the plant. In fact, at such levels of manuring crop removal may tend to deplete the soil of available phosphorus and potassium, and the levels should be checked periodically by soil analysis.

In conclusion it may be said that present evidence from manurial trials indicates that satisfactory crops of hops can be grown with much less manure than it has been traditional practice to give, in the past. Provided that soil analysis shows levels of available P and K in the high grade, then the following scheme, based on dung, may be regarded as safe for most conditions.

Manurial dressing	Nutrients supplied, lb./acre		
	N	P_2O_5	K_2O
15 tons dung	40	60	100
Inorganic fertilizers	140	60	100
Total	180	120	200

The inorganic fertilizer application can be made up in various ways, as for example, (per acre) 6 cwt. sulphate of ammonia (split into two or three dressings); 3 cwt. superphosphate and 1½ cwt. muriate of potash. If a compound fertilizer is preferred, then one with an analysis of 12 per cent. N, 12 per cent. P_2O_5 and 18 per cent. K_2O, applied at 5 cwt. per acre in the spring, supplemented with a later top dressing of 3 cwt. per acre sulphate of ammonia, would supply similar amounts of N, P and K. When the levels of soil available P and K fall to the medium-high grade, action should be taken, as a precautionary measure, to build-up these levels, although there is no consistent evidence from the present trials to show that yield suffers. Doubling the rates of phosphate and potash manuring to the equivalent of 6 cwt. per acre superphosphate and 3 cwt. per acre muriate of potash, should soon achieve this end.

When dung is not used, then the rates of application should be increased to make up for the nutrients supplied by the dung, but it should be emphasized that other sources of bulky organic matter should be used wherever possible. Of these, straw mulching is a promising alternative, but this needs additional nitrogen at the rate of at least 1 cwt. sulphate of ammonia per ton of straw, as well as additional phosphate and potash. Shoddy is a traditional alternative organic manure, and also supplies nitrogen in a slowly available form, but it is more expensive than dung when applied at rates supplying equivalent amounts of organic matter. The same applies and to a greater extent, with other organic manures, which are quite uneconomic when considered as suppliers of organic matter.

Finally, with regard to hop quality, the assessment of this is mainly a subjective process, and the question as to whether organic manures enhance hop quality is still a matter of opinion. Resin content is, however, recognized as an important factor, and the present trials have provided further evidence that organic manures do not increase resins. Further, there is no evidence to date that under normal field conditions different levels of NPK manuring have

any marked influence on resin content, though high nitrogen manuring does tend to depress resins and high potash manuring has the reverse effect.

As opportunity permits, further work is planned to study the effect of time of application of phosphate and potash fertilizers on hop growth and yield. This work will be related to fundamental studies, at present in progress, on the uptake of mineral nutrients by the hop plant throughout the growing season.

Acknowledgements

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THE EFFECT OF STRIPPING AND CUTTING UPON THE CARBOHYDRATE STATUS AND YIELD OF YOUNG HOPS

I. H. Williams

Summary

In 1960, young plants of the variety Fuggle N were grown from trimmed setts in 12½ inch pots. The treatments tested were: stripping of lower leaves and laterals to 5 ft. in May/June; cutting at the banding-in string in early September, as for machine picking; a control treatment—no stripping or cutting. Stripping reduced bine and root development for the remainder of the current growing season. It also checked the rate of build-up of carbohydrate reserves in the perennating rootstock. Cutting the bine at picking had less effect upon carbohydrate accumulation in the rootstock. In 1961, rootstocks from these treatments were planted in the field in a small randomized experiment. Yields were significantly heavier with the controls. Stripping young plants gave a more severe check in the following year than cutting the bine as for the machine. This experiment suggests strongly that, when replanting, full yielding capacity is likely to be attained more rapidly where stripping is reduced to the minimum.

Introduction

Earlier studies (Williams and Weston, 1959; Williams, 1960; Williams, Roberts and Coley-Smith, 1961) have shown that the carbohydrate reserves in the perennating rootstock of the hop plant play an important part in the annual growth cycle of the plant. Detailed chemical analysis of young plants taken throughout the year has shown that food reserves, primarily starch, accumulate in the roots and basal stem portions in late summer and early autumn, are gradually converted to available sugars during the winter dormant period and are utilized in spring and early summer as a source of energy for growth and development. The rate of accumulation or depletion of these reserves, at any specific time, will depend upon the balance of the photosynthates produced by the effective leaf area and the current utilization of carbohydrate material for growth, development or reproduction. The total quantity of these reserves at the end of a single growing season will also be influenced by the length of time during which the plant was allowed to carry its full leaf system as well as the effective size of the leaf system.

It follows that the practice of stripping the lower leaves and laterals from the bines in spring, up to about five feet to give better control of pests and diseases, and the removal of all but four or five

feet of the main bine at harvest time where machine picking is practised, are both likely to influence the processes described above. In the case of mature hops, picked when fully ripe, evidence from experiments at Wye (Thompson, 1955) and at Rosemaund (Jones and Moss, 1959) indicated that over a number of years neither stripping nor cutting had any marked effect on yield.

With young plants the picture is rather different. In the first three or four years the plant is building up carbohydrate reserves in its initially small rootstock. During this period of establishment, the size of the rootstock, and the carbohydrate reserves it contains, increase annually until a mature hill is formed, and it is clearly in the interests of the grower to assist the plant to reach this stage as quickly as possible.

The experiments described in the present paper were carried out at Wye in 1960 and 1961 and were designed to examine the effect of stripping and cutting upon the yield and carbohydrate status of plants in the first and second year of establishment.

Materials and Methods

General

Every effort was made to minimize variability due to differences in plant material or growing conditions. Trimmed setts of standard size of the variety Fuggle N were used and in 1960 were planted out in 12½ inch pots in John Innes potting compost No. 3, in the open in early March. A single bine from each plant was selected for uniformity of vigour and trained up strings on 12 ft. wirework. The pots were placed in rows, 2 ft. apart with 3 ft. between the rows. The outer rows were surrounded by a 12 ft. fence of hop lewing both as wind protection and to simulate as far as possible the shading effect between rows. Throughout the season the plants were irrigated and fed with liquid nutrients (Thompson, 1957) as required. Under these conditions growth was uniform and satisfactory and the effects of the treatments imposed were clearly evident. The advantage of growing the plants in large pots, in addition to the fact that this ensured that all plants had a uniform volume of a standard soil mixture, was that whole root systems could be washed out with minimum loss of tissue, for growth and chemical analysis.

Treatments

Four treatments were imposed upon batches of plants selected at random.

(1) 50 plants were allowed to grow naturally throughout the season ("control").
(2) 50 plants were stripped of leaves and laterals in two operations in late May and early June. The first stripping was up to three ft. from the base of the main shoot; the second stripping was up to five feet ("stripped").
(3) 25 plants were allowed to grow naturally as in (1) but were cut to within five feet of the main stem at the end of the first week in September ("cut").
(4) 25 plants were stripped as for (2) and cut back in the first week of September as for (3) ("stripped and cut").

Growth analysis

Two plants were sampled at weekly intervals from each treatment. The shoot system was separated into main bine and main leaves and later also into laterals, lateral leaves and cones as these developed. After careful washing out, the root system was separated into storage root (which also included the basal perennial portion of stem from which the new shoots arose, collectively referred to as the "rootstock") and the fine root system which is of annual duration.

The separate components were oven dried to constant weight. In addition to the dry weight data, the leaf area of one plant from each treatment was estimated at each weekly sampling.

Chemical analysis

The thicker roots and basal stem portion of two plants, comprising the storage organs, were cut up and a representative sample taken for chemical analysis. This sample was dried in a vacuum desiccator over silica gel, ground to powder in a small laboratory mill and stored at room temperature.

The powdered rootstock (2 g.) was extracted with 80 per cent. methanol, at room temperature, and the soluble carbohydrates determined by a colorimetric method (Yemm and Willis, 1954). The starch content of the extracted residue was then estimated by hydrolysis with dilute hydrochloric acid followed by determination of the reducing sugars by the Somogyi method (Association of Official Agricultural Chemists, 1960).

Results

The results are given in two main sections; (*a*) the effect of stripping and cutting upon growth, yield and reserve accumulation

in 1960 and (*b*) the "carry over" effect upon yield of plants grown on in the field in 1961.

(*a*) *Effect of stripping and cutting; 1960*

In the two stripped treatments the leaves were removed completely from the main bine up to three feet in late May and up to five feet in early June. Thereafter the basal five feet of the bines in this treatment were kept clean of leaves or laterals throughout the growing season. The removal of leaves at this stage resulted in a check to the development of the plants which was not made up subsequently. This can be seen in Fig. 1 in which the total dry

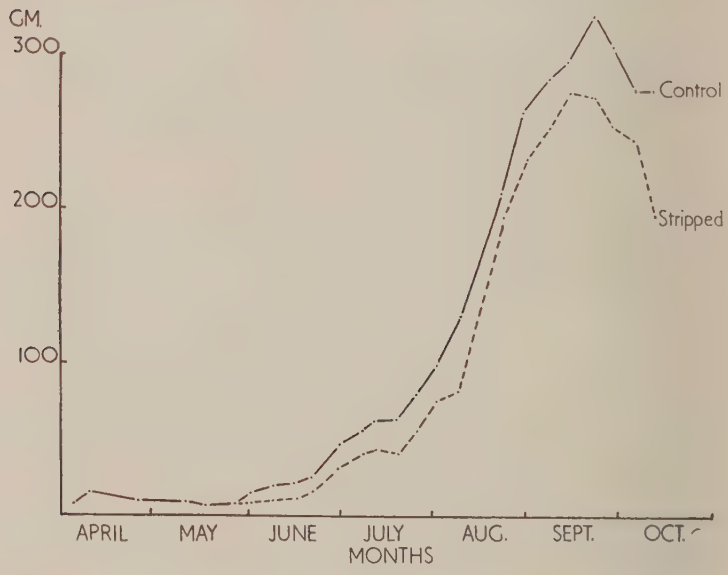

Fig. 1
Seasonal changes in total dry weight (including root system) of young hop plant 1960.

weight of the stripped plants including the entire root and shoot system, is shown. This was more evident with the root system than the shoot system, as Fig. 2 shows. The maximum dry weight of the storage organ (excluding fine roots) of the stripped plants was not more than half that of the controls. Although only a relatively small area of leaves was removed in May and June (Fig. 3) the effect was

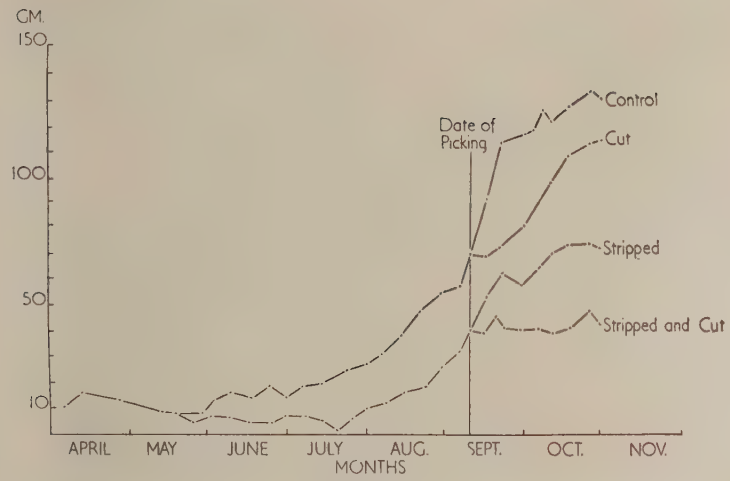

Fig. 2
Seasonal changes in dry weight of underground storage organ of young hop plant 1960.

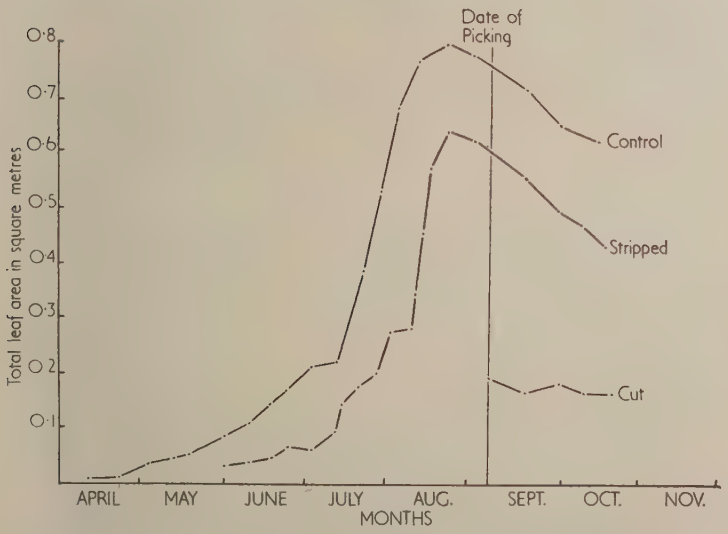

Fig. 3
Seasonal changes in total leaf area of young hop plant 1960.

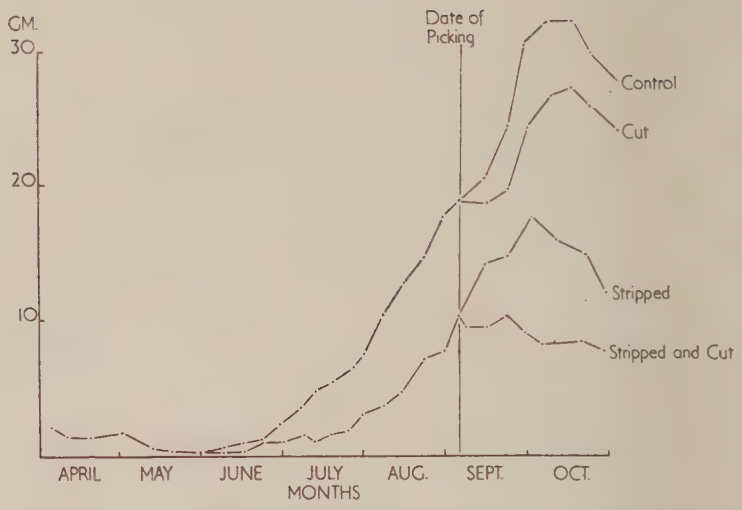

Fig. 4
Seasonal changes in total starch in the underground storage organ of young hop plant 1960.

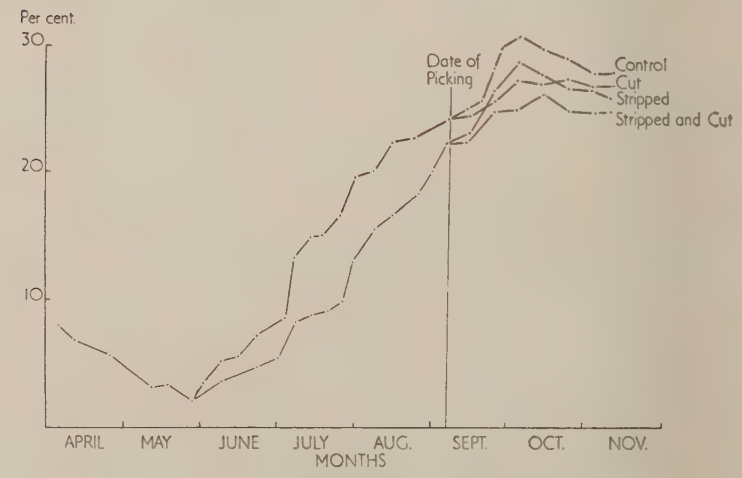

Fig. 5
Seasonal changes in per cent starch in the underground storage organ of young hop plant 1960.

cumulative, since laterals developed on the lower portions of the controls in June and July adding substantially to their leaf area, compared with the stripped plants. Stripping was carried out at a time when total carbohydrate reserves, principally starch, were at their lowest (Fig. 4) so that energy for growth and development after May was largely dependent upon current photosynthesis. Hence effective leaf area was likely to be vitally important during this latter part of the growing season. The percentage starch figures (Fig. 5) show that while stripping temporarily reduced the rate of accumulation of starch in the rootstock, there was no significant difference in starch content per unit volume of storage root at the end of the growing season.

Neither of the two cutting treatments influenced current yield or shoot growth, their effect being upon the continued build-up of storage material in the rootstocks. The controls continued to accumulate reserve carbohydrates until mid-October, when the leaves were visibly senescing (Fig. 4). The stripped plants also continued to accumulate reserves, though at a slower rate, up to about the end of September, when reserves began to fall. The cut but not stripped plants still retained an effective leaf area (Fig. 3) and continued to accumulate reserves at a rate very little less than the control plants, although the total amount of carbohydrate reserves was less. Very little, if any, further build-up of reserves occurred with the stripped and cut plants after cutting; this might be expected since the remaining five feet of shoot attached to the rootstock carried no leaves.

(*b*) *The effect upon yield; 1961*

Twelve plants from each of the four treatments tested in 1960 were planted in the field in randomized blocks in March 1961. The plants were carefully removed from the pots and planted with the entire ball of soil so that root disturbance was minimized and no storage root tissue was lost in the process. The plants were set out at the standard spacing of 6½ ft. square and were trained up 14 ft. wirework. Wherever possible eight strong bines were trained up the strings. Other basal shoots were removed but throughout the season no laterals or leaves were stripped, the plants being encouraged to carry as much leaf area as they were capable.

It was not possible, due to the limited number of hills, to carry out growth or chemical analysis during the growing season. However, it could be observed that plants which had been stripped and cut in

the previous season were visibly less vigorous and could easily be picked out on the basis of shoot development in June and July.

The hills were picked individually at harvest time and the yield figures are given in Table 1. It can be seen that the yields closely follow the pattern of the results for total starch for the different treatments obtained in 1960. The heaviest yield was obtained from the control plants which had been allowed to grow naturally in the previous year, while those which had been cut yielded less. The effect of stripping in the previous year markedly reduced yield and that of stripping and cutting was most deleterious.

Table 1

Effect of Cutting and Stripping Treatments in 1960 Upon Carbohydrate Storage in that Year and Upon Subsequent Yields in 1961

Treatment	Average weight of starch per storage organ Oct. 1960	Mean yield of dried hops per treatment Sept. 1961
	gm.	cwt./acre
Controls	31	9·8
Cut but not stripped ..	27	8·3
Stripped but not cut ..	18·3	5·6
Stripped and cut	10·1	4·8

Discussion and Conclusions

The initial carbohydrate reserves in the trimmed setts were small and, as the chemical analysis shows, were largely used up by mid-May to provide energy for root and shoot growth. Stripping was therefore carried out at a time when the further development of the plant was dependent upon current photosynthesis or, in other words, upon effective leaf area. The removal of the leaves in this operation checked the plant in two ways; it reduced bine and root development for the remainder of the current growing season, this being reflected in the reduced yield of the stripped plants in the subsequent year. It also checked the rate of build-up of carbohydrate reserves in the perennating rootstock, and at the end of the first growing season the stripped plants had a smaller rootstock than the controls. It is probable that the size of the storage organ increases in proportion to the rate of accumulation of carbohydrates and is a fair measure of the potential vigour of the plant, so that it is not surprising that the percentage carbohydrates did not differ significantly in any of the treatments from the controls.

Cutting the bine at picking had less effect upon carbohydrate accumulation in the rootstock. This was unexpected since, as Fig. 3 shows, the stripped plants which were not cut carried a considerably larger leaf area than the cut plants during the period of September and October when reserves continued to accumulate. From this evidence it would appear that the basal laterals, which generally remain vegetative, are of major importance in the replenishment of the rootstock reserves, whereas the leaves on the fruiting laterals are primarily concerned with the development of the current crop. This hypothesis is supported by the data given in Fig. 4, which shows that the build-up of starch in the rootstock, in plants which were cut but not stripped, was similar to that found in the untreated control plants and continued into mid-October, whereas with the stripped plants this build-up ceased in late September.

The importance of the quantity of reserves accumulated in the first year, upon the behaviour of the young plant in its second year of growth is clearly shown in the yield figures for 1961. In this year all the plants were allowed to carry their full complement of leaves, but those with smaller rootstocks, resulting from the previous year's treatments, failed to make up this disadvantage during the growing season and gave lower yields.

The conclusions reached in this experiment apply to young plants, and do not necessarily conflict with the results obtained in earlier experiments with established plants. In mature plants the primary function of the leaves is not to increase the carbohydrates in the rootstock, but to replace the reserves used-up in the current season's growth. Also, the reduction in total leaf area produced by stripping the lower leaves from a mature plant is considerably less than with a young plant. A further point is that on a mature plant, the lower leaves and laterals, if left on the bine, are likely to be heavily shaded during the latter part of the growing season, so that their photosynthetic effectiveness is correspondingly reduced. All these points suggest that stripping and cutting are less likely to reduce the yield of mature hills, except where the hills have been weakened by other factors such as drought, poor soil or inadequate nutrition.

The results of the present trial, however, emphasize that with young plants stripping should be reduced to the minimum necessary for disease control, and such plants should be hand picked if at all possible. In this way the plants should attain their full yielding capacity in the minimum time.

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HEIGHT OF WIREWORK AND SPACING TRIAL No. II: THIRD PROGRESS REPORT

PART I. CULTURAL DATA AND COMPARISON OF HAND AND MACHINE PICKING

F. C. Thompson and P. H. Bailey*

Introduction

Reports on the first and second years of this trial have appeared in previous Annual Reports (Thompson and Bailey, 1960, 1961) and in 1961 the trial was again used for a comparison of hand and machine picking. The experimental procedure was essentially the same as that used in 1960, the only difference being an increase, by a factor of two, in the number of samples taken for resin analysis. The machine was again run slowly with every other clamp loaded, and was run empty between plots.

Results

Yield

Table 1 shows the mean results for clean dry hops and "total dry hops" (i.e. including leaf and stem) expressed on an oven-dry basis.

Table 1

Overall mean yields, lb. per plant

Variety	Fuggle N		Northern Brewer		Bullion	
Picking Method	Machine	Hand	Machine	Hand	Machine	Hand
Clean dry hops ..	2·26	2·33	2·13	2·28	2·66	2·82
Total dry hops ..	2·44	2·39	2·29	2·33	2·86	2·89

The dry but dull season, adversely affected the crop which was considerably smaller, with all varieties, than in 1960 and somewhat smaller than that obtained in the dry, sunny season of 1959. With

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Fuggle and Northern Brewer the decrease in yield of clean dry hops, with machine picking, was much less than in 1960, and was not significant with Fuggle. With Bullion, however, the loss of yield was rather more than in 1960 and was highly significant.

With "total dry hops", the presence of more leaf and stem in the machine picked samples largely eliminated the yield differences between picking method.

As in the previous two years, the trends indicated by hand picking for response to height of wirework and spacing, were in general reproduced by machine picking, as shown in Fig. 1.

The increase in yield per plant with wider spacing, was significant except with machine-picked Northern Brewer. There was an indication of an interaction between height and spacing with Northern Brewer, wide spacing being less effective with low wirework; this interaction was evident with both hand and machine picking, but was more pronounced with the latter.

With height, Fuggle repeated the pattern found two years previously, in the dry season of 1959, yield increasing at 16 ft. but falling off at 18 ft. Northern Brewer, however, showed a progressive rise in yield with increase in height as in 1960. Bullion, with machine picking, also showed a steady rise in yield with increase in height, but with hand picking yield showed an appreciable drop at 18 ft.; this interaction between height and picking was significant.

As in 1960, the decrease in yield per acre with wider planting was marked and significant for Fuggle and Northern Brewer, with both hand and machine picking. With Bullion, however, the increase in yield per plant largely compensated for the smaller number of plants per acre and no significant yield depression was found with either hand or machine picking.

Composition of Samples

It can be seen from Table 2 that the machine-picked samples had an appreciably lower alpha acids content than the corresponding hand-picked samples. Correction of these results to a clean dry hop basis shows that much of this apparent loss was due to dilution of the sample with leaf and stem material.

As in previous years, neither hand nor machine picking indicated any consistent trend for alpha acids to vary with height of wirework or spacing.

Table 3 shows the mean proportions of the various physical fractions of the hops, expressed as percentages.

Table 2

Overall mean alpha acids contents

Variety	Fuggle N		Northern Brewer		Bullion	
Picking method	Machine	Hand	Machine	Hand	Machine	Hand
% total dry hops						
Alpha acids	4·5	4·9	6·6	7·2	6·4	7·0
% clean dry hops						
Alpha acids	4·9	5·0	7·1	7·4	6·9	7·2

Table 3

Mean Physical Composition of Samples

Variety	Fuggle N		Northern Brewer		Bullion	
Picking method	Machine	Hand	Machine	Hand	Machine	Hand
D.M. content of green hops %	20·50	20·61	23·52	23·48	26·26	26·80
Petal, % of d.m. ...	10·6	3·0	7·2	1·3	7·0	1·4
Leaf and stem, % of d.m.	7·4	2·7	6·8	2·5	7·1	2·5

Dry matter contents were much higher than in the wet season of 1960, but still well below the values obtained in the dry summer of 1959.

The petal fraction, which is an index of cone breakage, was similar to that found in 1960 with the hand-picked samples of Fuggle and Northern Brewer, but rather higher for Bullion. With machine picking, Fuggle showed a slightly lower petal fraction than in 1960, but with Northern Brewer and Bullion the values were appreciably higher.

Leaf and stem content with hand picking was rather lower for all varieties than in 1960. With machine picking Fuggle and Northern Brewer gave similar values but Bullion was higher than in 1960.

There were no significant effects of height or spacing on either the petal fraction or on leaf and stem content, but, in general, the highest petal content was found with the lowest wire-work, with all varieties, thus confirming the trend found in previous years—see Table 4.

Table 4

Effect of Height on Petal content, expressed as a Percentage of Total Dry Hops

Variety	Fuggle N		Northern Brewer		Bullion	
Picking Method	Machine	Hand	Machine	Hand	Machine	Hand
Height 18 ft.	10·12	2·65	7·34	1·28	6·82	1·27
16 ft.	9·50	2·96	7·03	1·14	6·31	1·36
14 ft.	12·28	3·37	7·08	1·56	7·91	1·46

Coefficients of Variation

The coefficients of variation obtained by the two picking methods, for the various factors investigated, are given in Table 5. Although variability was greater in 1961 than in 1960, the overall picture shows no essential difference between hand and machine picking.

Table 5

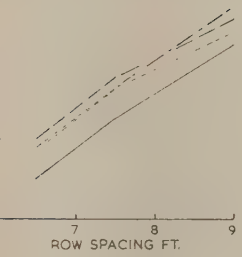
Coefficients of Variation

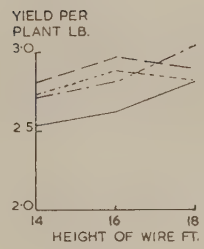
Variety	Fuggle N		Northern Brewer		Bullion	
Picking Method	Machine	Hand	Machine	Hand	Machine	Hand
Error (*a*)						
Yield per plant, clean dry hops . .	0·024	0·021	0·078	0·054	0·071	0·035
Total dry hops . .	0·022	0·021	0·077	0·050	0·075	0·035
Petal content . .	0·109	0·144	0·054	0·154	0·201	0·059
Leaf content	0·056	0·113	0·022	0·114	0·114	0·040
Error (*b*)						
Yield per plant clean dry hops	0·050	0–066	0·081	0·074	0·053	0·056
Total dry hops . .	0·060	0·067	0·087	0·080	0·052	0·053
Petal content . .	0·142	0·118	0·125	0·283	0·179	0·185
Leaf content . .	0·145	0·090	0·114	0·175	0·176	0·149

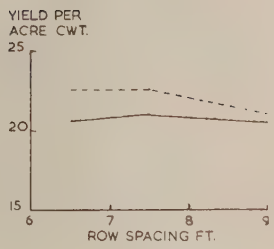
Discussion

As in 1960, the results for yield and resin content obtained by machine picking, were somewhat less than those found with hand picking, though with Fuggle and Northern Brewer the decrease in yield was less marked in 1961. The responses to the different height

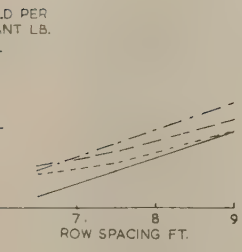
BULLION

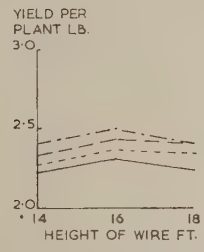


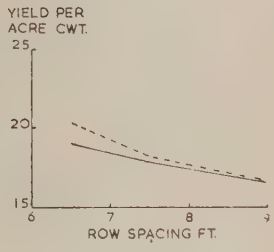




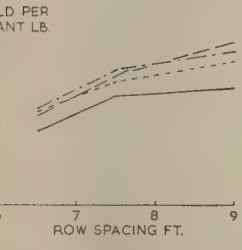
FUGGLE

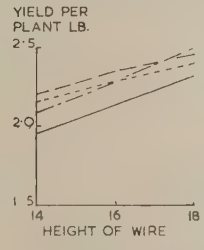


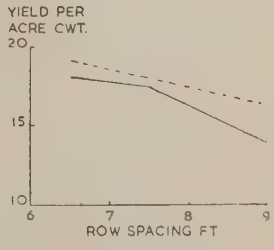




NORTHERN BREWER







KEY: TOTAL DRY HOPS

MACHINE PICKED — · — · —
HAND PICKED — — —

CLEAN DRY HOPS

MACHINE PICKED ————
HAND PICKED - - - - - - - -

FIG. 1

and spacing treatments were again similar with both picking methods, the only marked difference being with Bullion, where yield dropped with increase in height from 16 ft. to 18ft. with hand picking, but rose with machine picking. Overall variability was greater than in 1960, but the coefficients of variation were of the same order for both picking methods.

This comparison of hand and machine picking has now been carried out for three years, and the work has shown that while the results obtained by machine picking are not identical with those obtained by hand picking, the use of either method should enable similar conclusions to be drawn on the effect of experimental treatments on the yield of hops. Furthermore, machine picking has not been found to increase the variability, or experimental error, of the data obtained. This experiment is now concluded.

Acknowledgement

Acknowledgement is due to Mr. J. C. Gower of the Department of Statistics, Rothamsted Experimental Station, for arranging to carry out the bulk of the statistical analysis by electronic computer.

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Part 2. A NOTE ON YIELD DISTRIBUTION

I. H. Williams

Summary

Wider spacing resulted in a heavier yield per hill, the gain in yield being primarily on laterals on the lower sections of the bines. Higher wirework at constant spacing also increased yield per plant, though to a lesser extent; it did, however, give a better distribution of cones along the bine and a form more suited to machine picking than were observed at lower heights.

Introduction

In 1960 an attempt was made during the harvest period to assess the influence of different heights of wirework and spacing of hills upon the distribution of cones along the bine. Hills were selected at random from each treatment block and the number of mature cones on measured sections of the bines was counted. Results indicated that wider spacing resulted in an increase in the number of mature cones which developed on the lower laterals of the bines, whereas higher wirework resulted in a better form of plant for machine picking, with less tendency for the formation of a tangled head and cones in the upper regions of the bines borne on shorter laterals over a longer length of bine (Williams, 1961).

The procedure of counting cones proved very time-consuming and limited the number of hills which could be examined from each treatment. Owing to sampling errors a close relationship between cone number per hill and the dry weight yield data recorded in the main experiment was not obtained. In 1961 therefore a simpler technique was adopted, described more fully below, in which the dry weight of cones from each measured section of the bines was recorded instead of cone number. The results obtained showed good agreement with the yield data for each plot recorded in the main experiment and largely confirmed the findings of the previous year.

Materials and Method

Thirty-two hills were selected at random from each of the three varieties Fuggle N, Northern Brewer and Bullion. Within each variety eight hills were examined from each of the following treatments:

14 ft. × 6½ ft.; 14 ft. × 9 ft.; 18 ft. × 6½ ft.; 18 ft. × 9 ft.

Strings, each comprising two bines, were severed from the parent plant at the banding-in string, care being taken to include the

portion of the bines overhanging the top wire. The individual strings were cut into three foot sections starting from the point at which they had been cut from the parent plant. The terminal section, consisting of a portion of the bines immediately below the top wire and the portion which had grown over the top wire (the most distal portions of the bines), was of variable length and is termed in this paper the "head". From each section of string the cones were picked and weighed and the samples dried overnight in the oast. The produce from each hill was sub-sampled for determination of total dry matter, by oven drying.

Results

(1) *Spacing effect*

In Table 1, total yields are given in lb. per hill, oven-dry weight. With all varieties wider spacing at the same height produced a heavier yield of cones per hill. This may reasonably be attributed firstly to less root competition in the rows at the wider spacing and hence less competition for water and nutrients. Looking more closely at the distribution of cones up the individual bines, as shown in Table 2, it can be seen that the gain in yield at the wider spacing was most marked on the lower sections of the bines. With wider spacing the lower parts of the bines receive more light and this may enhance photosynthetic activity in the lower leaves and laterals and result in better cone development at these levels. The previous year's study also showed that, at the closer spacing, many cones remained small and failed to develop to maturity.

(2) *Height effect*

Higher wirework also resulted in a gain in yield per hill, though the increase was less than that found with wider spacing. As can be seen from the distribution data given in Table 2, with higher wirework at the same spacing, there was actually a decrease in the weight of cones produced on the lower part of the bine, below 9 ft. This, however, was more than compensated by the increased yield obtained on the upper part of the bine.

Upon reaching the top wire during the spring phase of rapid elongation, the terminal portion of the now unsupported main bine, on continuing growth, must either bend over and become "kinked" or be broken-off in the wind. In either case there will be a check to extension growth and a loss of apical dominance, causing further vegetative growth to be concentrated mainly in the laterals on the upper section of the bine. This check to further growth of the main

bine will occur earlier on 14 ft. wirework. At 18 ft. not only will the main bine continue to develop unchecked for a longer period but the check will occur later in the growing season, when more laterals have been laid down. The effect of this upon yield would appear to be firstly that on the 18 ft. wirework cones are distributed over a greater number of laterals on a longer length of bine, and secondly, that the check to extension growth which occurs earlier on the 14 ft. wirework results in fewer, though larger, laterals on the more distal portions of the bine, but a drop in total yield. In other words, the larger laterals do not compensate for the loss of main bine on the lower wirework. An additional advantage of the higher wirework would seem to be that the cone distribution and the absence of a tangled head gives a form of growth better suited to machine picking.

(3) *Varietal effect*

The advantages in yield and cone distribution at the wider spacing and on the higher wirework are seen to be most marked with Bullion, the most vigorous variety, and least marked with Fuggle.

Conclusions

Trials over a number of years have established that with hops both wider spacing and higher wirework increase yield per plant, though the increase is smaller, and less consistent, with higher wirework. The present investigation was designed to study how this increase is obtained, and it has been shown that with wider spacing there is a marked increase in the weight of cones produced on the lower part of the bine. By contrast, with higher wirework the increase occurs on the upper part of the bine and is also associated with a more even distribution of cone bearing laterals along the bine, which is an advantage with machine picking. With wider spacing the pattern of growth is not so suitable for the machine and, in addition, the increase in yield per plant does not, in general, compensate for the fewer hills per acre and yield per acre falls. The results from the present study support the findings of the experiment as a whole, that for machine picking increasing the height of wire work is to be preferred to wider planting.

Reference

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Table 1

The effect of height and spacing treatments on yield per hill. Mean values expressed in lb. oven-dry hops

Variety	Height	Spacing	
		6½ ft.	9 ft.
Fuggle	14 ft.	2·27	2·37
	18 ft.	2·33	2·61
Northern Brewer ..	14 ft.	1·92	2·23
	18 ft.	2·21	2·59
Bullion	14 ft.	2·24	3·25
	18 ft.	2·65	3·32

Table 2

The effect of height and spacing treatments on the distribution of hops along the bine, measured in five sections. Mean values per hill expressed in gm. oven-dry hops

	Position of sections above banding-in string.					Total per hill
	0-3 ft.	3-6 ft.	6-9 ft.	9-12 ft.	Head	
Fuggle						
14×6½ ft.	49	145	584	—	253	1031
14×9 ft.	150	244	419	—	265	1078
18×6½ ft.	20	110	211	400	259	1060
18×9 ft.	121	152	240	400	270	1183
Northern Brewer						
14×6½ ft. ..	201	233	207	—	232	873
14×9 ft.	235	271	249	—	258	1013
18×6½ ft.	151	207	228	255	164	1005
18×9 ft.	193	272	253	268	190	1176
Bullion						
14×6½ ft.	23	77	465	—	455	1020
14×9 ft.	89	232	507	—	650	1478
18×6½ ft.	20	55	296	458	374	1203
18×9 ft.	126	264	312	415	389	1506

THE HANDLING OF PLANT MATERIAL AND THE DISPOSAL OF WASTE RESIDUES IN RELATION TO THE MECHANICAL PICKING OF HOPS

D. G. Martin

Summary

Investigations were carried out during 1959-1961 on problems involved in (*a*), the handling and transport of hop bine material (in the form of strings) from the field to the picking machine; and (*b*), the disposal of the waste plant residues produced by machine picking. Detailed surveys were carried out of present methods of transporting strings, and intensive examinations were made by work study techniques of 16 typical hop farms. These surveys, to which more than 90 per cent. of all English machine-users contributed information, established that in 85 per cent. of cases, tractor-drawn trailers were used for transport; in 80 per cent. of cases the strings were pulled down from the top wire and then loaded on to the transporting vehicles. It is tentatively recommended that systems of string transport should be used in which workers in crow's-nests cut the strings from the wirework and allow them to fall gently into position in trailers.

The surveys also revealed that methods of waste disposal were much affected by the presence or absence of bine-chopping equipment on the picking machines. Chopped waste was difficult to burn and was usually composted. Unchopped waste was commonly burned, especially in dry seasons. Well rotted waste material is approximately equal to farmyard manure in manurial value and is used as a bulky organic fertilizer for fruit and other crops on many hop farms. The possibility was investigated that progressive *Verticillium* wilt might be spread in such compost made from residues of wilt-tolerant varieties growing on infected soil. It was found that well made compost heaps of waste material, heated sufficiently through biological activity will eliminate most if not all of the wilt infection originally present. Composting is therefore recommended as a safe method of waste disposal in areas where progressive wilt is already established. General advice is given on composting methods and on the use of compost as manure in wilt areas. In areas where progressive wilt is not yet established, waste residues should be burned where possible, especially on farms with new outbreaks of the disease.

Introduction

During the last fifteen years, revolutionary changes have taken place in English hop picking methods. In 1947 almost the whole of the crop was picked by hand with not more than 8 picking machines in use. In 1961 nearly 75 per cent. of the English crop was picked by 544 stationary machines distributed throughout the hop growing areas as shown in Table 1.

Table 1
1961 Hop-picking season, Numbers of Growers and Machines

District	Total Growers	Growers using machines	No. of machines
1. South Eastern Area	496	279	293
2. Farnham Area (Hants) ..	27	18	19
3. West Midland Area	250	182	198
4. Brewer-growers and Contract-growers (not included above)	19	18	34
Total	792	497	544

The change-over to mechanized hop-picking has introduced several husbandry problems to hop growers. Work carried out during 1959-1961 by the writer in the Hop Research Department, Wye College, on a postgraduate scholarship provided by the Hops Marketing Board, was designed to investigate two of the more important of these problems:

(1) The handling and transport of the strings from the hop garden to the picking machine.

(2) The disposal of plant residues after picking, particularly when infected with progressive wilt fungus, *Verticillium albo-atrum*.

The more important facts which emerged from the work are summarized in this paper.

The Handling and Transport of Plant Material from the Hop Garden to the Picking Machine

The lack of satisfactory mobile or portable machines capable of picking hops *in situ* in the garden has resulted in the universal use of stationary machines. Picking hops with a stationary machine requires the removal of plant material in the form of "strings" from the garden and the transport of these strings to the machine. In machine picking parlance the string is the basic unit of plant material. There are from two to four strings per hill and each is from 10 to 15 ft. long depending on the height of the wirework. Each consists of the coir fibre or string up which the hop plant is grown together with one or more mature bines twined round it, usually with the head portions of the bines still attached. The strings are cut off from the hill at from 2 to 5 ft. above ground level and are detached from the top wire by either pulling or cutting.

The hop grower is faced with the problem of handling the strings to bring about their removal from the wirework in the garden, and to transport them to the machine for picking. In the early days of machine picking, growers were too preoccupied with the imperfections of the machines themselves to give more than passing attention to the method by which the strings were handled. At the Wye College Hop Grower's Conference in 1946, one of the pioneers among machine users said "The haulage of the bines is no problem; no special equipment is needed other than protective clothing for pulling in wet weather"—an observation scarcely borne out by subsequent experience. Later, however, in their preliminary survey of hop picking machines, Gibb and Chater (1951) recorded that the widest scope for improvement in hop-picking machine management was in the collection of strings from the hop garden or yard.

In their second survey of hop picking machines, Gibb and Chater (1952) reported more fully on the methods then used for handling strings. In the main trailers were used, sometimes with a crow's-nest. The coathanger system, consisting of hooks on racks carried on a special framework over the transporting vehicle, had come into operation as a result of the need felt for more careful handling of the strings. Some growers coiled the strings up before loading them, others laid them flat on the beds of trailers. Lorries were sometimes used and trailers were in some cases drawn in tandem. Gibb and Chater emphasized the need for more careful handling of the material and noted that changes in methods were taking place at the time of writing.

In a later paper, Chater (1954) gave more detailed consideration to handling methods, stating that their object was to supply 12-16 strings per working minute in good condition at the machine loading point. Methods in use at that time included flat trailers, sometimes with a canvas sheet on the floor which could be pulled off with the load of strings at the machine: coathanger systems: tractors with mounted wooden platforms: trailers with crow's-nests: and trailers with a turntable which assisted positioning for unloading. Commenting on the efficiency of these different systems, Chater criticized trailers where their use caused damage to the strings and interrupted the feeding of the machine; he also stated that crow's-nests required more labour and were slower than other methods. The subject was further discussed a year later by Chater and Jary (1955).

In a paper given at the 1959 Maidstone Hop Growers' Conference, Armitage (1959) stressed the importance of the strings

arriving at the machine in as fresh a condition as possible. The coathanger system, while ideal for gentle handling of strings, was condemned as too cumbersome and slow; systems in which the strings were laid lengthways on top of one another, caused damage to the lower ones. Mention was made of the necessity for some device to hold the butts of the strings in sequence, and it was emphasized that if the strings were laid straight on the vehicle, they would more easily "peel off" the load at the machine.

Armitage also pointed out that damage, with consequent financial loss, could occur from excessively fast transport over rough terrain. In his opinion the crow's-nest method enabled the strings to be handled with more care than in most other systems, resulting in less waste both in the garden and at the machine. With crow's-nests it was important that the terrain be fairly flat, and the wirework of an even height to facilitate working and prevent accidents.

At the London conference of the European Hop Growers' Convention, Knakal (1960) discussing the mechanical harvesting of hops in Czechoslovakia, mentioned the importance of better handling of bines. He referred to the need for care in their gathering and transport and in loading on to the machine if losses were to be reduced.

In general terms, the process of handling and transporting strings should fulfill the following basic requirements:

(1) Cost is a prime consideration. Inefficient use of labour and machinery should be avoided, but this economy should not be enforced to the extent that operators and machinery become overworked.

(2) The process should be simple, and so designed that the operators do not become unduly fatigued.

(3) Good understanding and supervision are essential in order to prevent the operation becoming divorced from that of the picking machine. Close co-operation between garden and machine work should be maintained at all times.

(4) The input rate for stationary machines varies from 8-24 strings per minute according to their size. This supply must be maintained.

(5) The supply of strings should be regular, without the need for an excessive rate of work, which can cause damage to the hops and equipment.

(6) The strings should arrive at the machine in as fresh a condition as possible; the minimum possible time should

elapse between the cutting down of the string and its subsequent entry into the machine for picking.

(7) The material should not be unduly damaged or wasted. Damage means loss of value, waste means loss of material. The amount of detached lateral and loose hops should be kept to a minimum.

(8) Whatever form of vehicle is used, the loads, on arrival at the machine should be able to be easily and quickly moved into position for feeding into the machine so that the butts of the strings are clearly visible and easily handled. The strings should "peel off" the load, without damage caused by pulling and tearing when lifted by the binetrack.

Among hop growers at the present time there is wide diversity in respect of their chosen method of handling and transporting the strings. The work at Wye began by an investigation of the range of methods in use.

A survey of all hop-picking machine users in this country was carried out, and information was obtained on the many different systems employed during the 1959 picking season. The response to this survey was excellent, being answered by 92 per cent. of all machine users.

Using this information, the systems were classified, and later sixteen farms which were examples of the more common systems were chosen as "Case Studies". A Work Study investigation was carried out on each of these during the 1960 season, and from the results of this it was possible to draw general conclusions on the handling and transport process as a whole, and to note some of the principal advantages and disadvantages of each system.

From the survey it was found that all systems used in the handling and transport operations could be classified as follows:

Class A. Systems involving a tractor drawing a trailer or trailers.

(1) Trailers with drawsheets.
(2) Trailers with crow's-nests.
(3) Trailers only; usually with wickets.*
(4) Trailers with coathangers.
(5) Trailers with binecombs.
(6) Trailers with any other special fitting.
(7) Trailers drawn in tandem.

* A wicket is a device very commonly used to hold the butt ends of the strings in an orderly sequence on the transporting vehicle. It consists of two or more upright metal tubes at one end of the vehicle so grouped that the ends of the bines can be secured in sequence by placing firmly between the tubes.

Class B. Systems involving a container mounted on a tractor.

(1) Tractors with pallets.
(2) Tractors with buckrakes.
(3) Tractors with mounted platforms.
(4) Tractors with any other special fitting.

Class C. Systems involving the use of lorries.

(1) Lorries with coathangers.
(2) Lorries with binecombs.
(3) Lorries with crow's-nests.

Class D. Systems other than A, B and C above.

(1) Mobile machines.

The relative extent to which these systems were used during the 1959 hop-picking season is given in Table 2.

TABLE 2
1959 HOP-PICKING SEASON. SYSTEMS USED FOR TRANSPORTING STRINGS

Method Used		Number	% Total
Class A	*Tractors and trailers with:*		
	1. Drawsheets	85	22·0
	2. Crow's-nests	35	9·2
	3. Wickets only	168	44·0
	4. Coathangers	12	3·1
	5. Binecombs	3	0·8
	6. Special fittings	3	0·8
	7. Trailers in tandem	22	5·5
		328	*85·4*
Class B	*Tractors with:*		
	1. Pallets	24	6·5
	2. Buckrakes	3	0·8
	3. Mounted Platforms	14	3·7
	4. Special fittings	1	0·3
		42	*11·3*
Class C	*Lorries with:*		
	1. Coathangers	6	1·5
	2. Binecombs	4	1·1
	3. Crow's-nests	1	0·3
		11	*2·9*
Class D	*Mobile Machines*	2	0·5
	Total	383	

Factors which Influence the Choice of a Handling and Transport System

From evidence brought to light by the Case Study Investigations it is possible to summarize the factors which govern the choice of a handling system. These are as follows:

(1) *The available resources on the farm*

(*a*) *Labour*

The amount of labour available and its quality in terms of ability to tolerate sustained manual work, or drive tractors or lorries.

(*b*) *Machinery*

The available machinery already in existence on the farm, or to which the farm has access.

(*c*) *Capital*

The availability of capital for investment on specialized hop equipment governs the choice of system to a large extent. Growers with little available capital may not be prepared to invest in equipment which will only be in use for 3-4 weeks of the year. In such cases the best use must be made of equipment which can be put to other uses on the farm. Where capital is available systems which involve the use of specialized equipment may be chosen.

(2) *The type and construction of the machine*

(*a*) *Size of machine*

Large capacity machines require a system capable of maintaining a high rate of loading and an adequate supply of material to the machine.

(*b*) *Type of binetrack*

Choice of binetrack design is sometimes governed by consideration of the space available, or by capital restrictions. The system chosen must be suitable for the particular type of binetrack installed on the machine.

(*c*) *The siting of the machine in relation to the hop gardens*

The distance which the material may have to be hauled, and the type of surface over which this travel takes place, must be considered.

(3) *The growing of the hops*

The system of wirework, stringing and training limits choice of system to a certain extent. The type of soil may influence the likelihood of heavy transport vehicles becoming stuck and causing damage

in wet weather, and the associated risk of damage to the hills from the wheels of vehicles.

The terrain may also affect the choice of system, because steep slopes may make the use of systems involving crow's-nests or mounted platforms a dangerous and difficult practice.

(4) *The personal preference of the grower*

This factor cannot be assessed, but prejudices against certain systems are likely to exist.

The different systems in use have been examined, and some of the factors which influence the choice of a handling and transport system have been analysed.

Although each Case Study was chosen as an example of a particular system of handling, each was only representative in the precise sense of the word of the situation *on one farm*. The operation of any *one* system on any *one* farm reflected largely on the ingenuity and managerial ability of the grower himself; in this respect hop growers were found to be highly individualistic.

With a small number of Case Studies it was not possible to make hard and fast comparisons between different systems of handling and organization, but some of the facts brought to light by this approach were found to have more general application. The following tentative recommendations can be made:

(1) The strings should be cut down rather than pulled from the top wire. Where possible, cutting the strings from the hills should be a spare time job for the loaders.
(2) The strings should be loaded direct on to the vehicle wherever possible; systems should be avoided which entail pulling down and carrying.
(3) A wicket device should be used to keep the strings in sequence on the load and to make their butt ends clearly visible.
(4) The loads should not be packed down too hard; overloading, which causes damage from crushing and tangling, should be avoided. The loads should be allowed to build up naturally.
(5) The amount of clearing up in the garden should be kept to a minimum; wasteful use of labour for such work should be avoided.
(6) Automatic hitches should be used wherever possible.

(7) Sufficient labour and transporting vehicles should be available to keep the machine fully supplied.
(8) The binetrack on the machine should be arranged so that:
   (*a*) feeding may be from both sides of the track;
   (*b*) the strings may be fed directly off the transporting vehicle without extra handling.
(9) The feeding of the strings into the machine should be organized so that every clamp is filled, and that there is no gap between successive loads.
(10) There should be clear division of labour, so that each man knows exactly what he has to do. Where jobs are inter-changed, a regular rota should be followed.

The first five of these recommendations are concerned with the handling of strings in the garden or yard. While the evidence available is insufficient to permit of dogmatism, it would appear that under English conditions at present, the most efficient system is one which employs workers in crow's-nests to cut down strings from the top wire. In this way, pulling of strings, with consequent shattering of heads of bines, is avoided and cleaning up work is reduced to a minimum (recommendations Nos. 1 and 5). If the crow's-nests are suitably placed and used, the strings can be made to fall gently by gravity along the length of the transporting vehicle, thus reducing work and giving a natural and untangled build up of the load (recommendations Nos. 2 and 4). The necessity for some form of wicket device for orderly retention of the butt ends of the strings (recommendation No. 3) is so generally accepted as to need no comment.

From experience gained in the course of this work, it would appear that some system in which removable crow's-nests can be placed temporarily on the trailers used for transport is probably the most suitable and is cautiously recommended where circumstances permit of its use. It should be emphasized, however, that such a system can be unsafe on steeply sloping ground or where there are marked irregularities in the height of the wirework.

In this connection, it is of interest to note the findings of Brown and Allsopp (1951) as recorded in the report published by the Anglo-American Council on Productivity. In this they describe the methods used in 1950 by American growers for transporting strings to the picking machine. Tractor-drawn four-wheel trailers were normally used for short hauls, but for long hauls on public roads lorries were used. The vehicles were fitted with crow's-nests in which

operators stood with their heads just below the height of the wire-work.

To gather the bines, the strings on each side of an alley were cut at a height of four feet and left hanging. As the trailer or lorry moved up the alley, operators at the front end gathered in the butts and secured them in the equivalent of a wicket device. The men working in the crow's-nests then cut the strings at the top wire so that they fell gently along the vehicle. It was noted that this American system used more labour than English methods in use in 1950 but that the great care taken during the whole operation resulted in little tangling of strings and a minimum amount of damage.

Current evidence suggests that while in modern American practice lorries have largely replaced trailers for transporting strings, the use of crow's-nests is still universal. American knowledge and experience of machine-picking techniques is much greater than can in general be found in England today; in view of this, crow's-nest systems of a type suitable for local conditions can be the more strongly commended to English growers.

The Disposal of Plant Residues from Hop Picking Machines with Special Reference to Progressive Wilt

It has long been held that when the hop plant is harvested, the weight of cones picked is approximately equal to the weight of the plant material that remains. Recent work at Wye by Williams (1960) and Bailey (1961) has enabled estimates to be made of the amount of waste residues produced by hop picking machines and these estimates confirm the accuracy of the traditional belief. Under English conditions, the weight of waste material, while varying with the size and nature of the crop, is approximately equal to the weight of cone material harvested and is of the order of 4-6 tons of green material per acre. The volume of space occupied by this material may vary greatly depending on degree of compaction and density. Measurements have shown that one cubic yard of hop waste may weigh as little as 1-2 cwt. or as much as 7-8 cwt.

On the basis of a range of analysis values provided by the National Agricultural Advisory Service at Wye, an estimate of the manurial value of composted hop-picking machine residues has been obtained. The figures, calculated on a wet-weight basis, are set out in Table 3 where commonly accepted figures for farmyard manure are given as a comparison.

Table 3

	Dry Matter %	Nitrogen % (Total N_2)	Phosphate % (P_2O_5)	Potash % (K_2O)
Hop picking machine waste ..	25	0·50	0·20	0·43
Farmyard manure ..	25	0·55	0·25	0·55

Although slightly lower in nitrogen, phosphate and potash, the composted waste compares favourably with farmyard manure and must be regarded as a valuable form of bulky organic fertilizer. This is an important fact when it is considered that many hop farms produce less organic manure than is required for the maintenance of adequate soil fertility in their hop gardens.

Waste plant material from hop-picking machines may be classified into two main categories:

(1) Residues from machines with some form of bine-chopping mechanism. Such residues are discharged at a single outlet and consist of a mixture of all the waste material (including the hop string) in a relatively finely broken condition.

(2) Residues from machines with no bine-chopping mechanism. Here the picked bines and the hop string are discharged whole and unbroken at one outlet, while the remaining waste, comprising a mixture of leaf, trash and petal material, is discharged in a relatively fine state at another outlet.

Information in respect of the 1959 crop obtained from the survey of hop picking machine users referred to above, showed that waste residues were disposed of by one of three main methods:

(*a*) Dumping in disused pits or quarries;
(*b*) Burning;
(*c*) Composting.

The choice of method was greatly influenced by the presence or absence of bine-chopping equipment. A total of 236 growers had bine-chopping mechanisms fitted to their machines. Of this total 192 or 80 per cent. composted their waste, 23 dumped it in pits or quarries while only 18, or less than 10 per cent., burned it.

A total of 146 growers had no bine-chopping attachment to their machines, and of these only 6 or 4 per cent., composted their waste. In this category 20 growers dumped their residues while no less than 120 or 80 per cent. burned their waste material.

Of the 198 growers who composted their waste residues, 56 used an additive—usually sulphate of ammonia.

Recent work at East Malling Research Station has established that fresh waste residues from hop-picking machines on farms infected with progressive wilt may contain appreciable quantities of *Verticillium albo-atrum* (Sewell and Wilson, 1961). This is especially the case where there is a high incidence of symptomless infected plants in wilt-infected gardens. The amount of infection in the fresh waste may theoretically be reduced by more rigid control on the part of the growers over the plants which are picked, involving the rejection of plants showing wilt symptoms. The practical difficulties of this approach are so great, however, that it must be accepted that all picking machine residues on wilt farms will be infective to a greater or lesser degree.

While few if any growers use composted hop residues to manure their hop gardens, such material is commonly applied to a wide range of other crops. The risk of spreading progressive wilt by this practice is obvious and is rendered the more insidious by the fact that the disease may gain a foothold unnoticed in clean land through symptomless infection of alternate host plants.

The disposal of waste residues on wilt-infected farms is therefore a problem of major importance. Of the three methods described above, dumping is impossible for the vast majority of growers owing to the lack of suitable sites in the form of disused quarries or pits.

Burning the waste material, if efficiently carried out, can be regarded as the only really safe method. While this is usually possible without special equipment in the case of waste with unchopped bines, it is extremely difficult with chopped material. In a wet season it becomes almost impossible to accomplish with any form of material. The only sure method of burning is by the use of some form of incinerator. There are two difficulties in connection with possible incineration. First, no suitable equipment has yet been developed; second, the results of preliminary enquiries suggest that the cost of an incinerator may prove to be beyond the means of more than a few growers. A general disadvantage of the burning method is the loss of the material as organic manure.

Disposal by composting recommends itself to a majority of growers and the effect of this method on the infectivity of waste material from wilt-infected gardens was studied jointly by Wye and East Malling Research Station. Investigations during 1959-60 and 1960-61 at a range of sites in south-eastern England showed that biological activity in heaps of carefully made hop-waste compost

invariably caused extensive heating. In some cases temperatures as high as 80° C were recorded. The amount of heat generated depended on the degree of compaction; aerobic conditions favoured higher temperatures. Sustained temperatures of 45° C or over for more than 12 hours are known to be lethal to the progressive wilt fungus (Talboys, 1961) and it was shown that such temperatures were common in the central parts of compost heaps.

The periphery of heaps (to a depth of 12 inches) did not heat consistently to lethal temperatures. Efforts to ensure this by insulation with straw or masonry were not entirely successful. It was found that turning heaps so that the former peripheral material was placed in the centre of the remade heaps was followed by rapid heating to temperatures lethal to progressive wilt.

The evidence obtained in this work indicated that the process of composting might eliminate much of the progressive wilt infection originally present in the waste material and this possibility was carefully investigated. An account of this work has already been published (Sewell, Wilson and Martin, 1962); details are summarized below.

Four types of hop waste material were examined:

(*a*) Infected bine material;
(*b*) Clean bine material;
(*c*) Infected leaf and stem trash;
(*d*) Clean leaf and stem trash.

Control samples of (*a*) and (*c*) were stored in the laboratory under air-dry conditions while the remaining samples were enclosed separately in fine nylon mesh and placed in a heap of residues from a picking machine on a wilt farm, in October 1960. The samples were grouped in a range of sites at different levels in the heap, clean and infected samples being placed contiguously at each site to observe the spread of infection, if any, under the conditions obtaining in such a compost heap. Temperatures were recorded at each site using mercury-in-glass thermometers in conduit tubes. These records showed that the heap heated in the normal fashion and that temperatures lethal to progressive wilt were reached at all sites except those on the periphery of the heap.

In March 1961, the samples were recovered from the compost heap and were tested for infectivity by the normal field test method at East Malling during the summer of 1961. The air-dry control samples were also included in the test, a total of 200 samples being so examined. All the air-dry infected material proved highly infective. The remaining samples showed no infection, except one

sample of infected trash which had been placed in a peripheral site in the heap where lethal temperatures had not been recorded. In general, however, the infectivity of the material in the peripheral layers proved to be much lower than would have been expected from the temperatures recorded there.

From these results it was concluded that normal composting of waste residues could be expected to eliminate most of the wilt infection present. No evidence was obtained of contamination of clean compost by the wilt fungus spreading from areas which had not been sterilized by high temperatures.

In view of the findings of this work, it is felt safe to recommend the composting of machine residues to growers in areas such as the Weald of Kent where progressive wilt is firmly established. Precise information on the best methods of composting these residues is not at present available and further research on this problem may prove to be necessary. The following general advice, based on the work of Lambert (1957), can be given:

(1) Where possible a firm base and retaining walls should be provided to contain the heap and facilitate movement of the composted material. Good drainage is essential.
(2) The material should be spread evenly over the area of the heap; compression and compaction should be avoided as far as possible.
(3) Air inlets are usually necessary to encourage aerobic activity by micro organisms and should be provided.
(4) Heaps should be long and flat rather than short and high; they should be covered with straw or some similar material as soon as possible after completion to insulate against heat loss.
(5) Additives should not normally be necessary.
(6) The heaps should be turned at least once and preferably more often, putting the outer material into the centre of the new heap at each turning. This will encourage reheating and so increase the probability of complete elimination of wilt infection. It will also produce better compost.
(7) The compost should be left as long as possible before use.

Compost so produced in wilt areas should be used as manure with caution since it must always be regarded as a potential carrier of progressive wilt. It may if necessary be applied to already infected hop gardens where wilt-tolerant varieties are being grown; it should never be used to manure wilt-sensitive hop varieties, nor should it be put on land which is likely to be planted up with hops in

the future. It may safely be used on non susceptible crops such as corn or orchards under grass, but care should be taken to see that it is always put on the same land in successive years and not allowed to contaminate the whole farm by indiscriminate use.

In areas such as East Kent and the West Midlands where progressive wilt is not yet established, a more cautious approach is necessary. From a plant health point of view it is wisest, as a precautionary measure, to burn machine residues on all hop farms in such areas. Where composting is carried out because of convenience or economy the advice given above should be carefully followed. In the case of a farm with a new outbreak of wilt in a wilt-free area, every effort should be made to burn all the waste material until the outbreak is suppressed.

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APPENDIX I

THE CHALLENGE CUPS FOR THE NEW VARIETIES OF HOPS

F. H. Beard

The eighteenth annual exhibition of New Varieties was held, under the auspices of the Institute of Brewing, at 15 Southwark Street, London S.E.1., on 22nd and 23rd November 1961. As in previous years the show was organized by Messrs. Wigan, Richardson and Co. As has been usual in recent years added interest was provided by a number of non-competitive exhibits. This year these exhibits consisted of a sample of the triploid seedling WFT2, samples of American hops lent by Messrs. Edward Strauss and Co. and an oblong *bale* of hops. A "back cloth" was provided by copies of some 100 newspapers which had carried Brewers Society advertising during the past year.

Three challenge cups are competed for as follows:

(1) The Brewers' Cup; for hops intended as substitutes for American hops; this cup was presented in 1944 by Messrs. Barclay, Perkins, Messrs. Guinness and Messrs. Whitbread.

(2) The Growers' Cup; for hops intended to augment English commercial varieties; this cup was presented in 1946 by the Association of Growers of New Varieties of Hops.

(3) The Hop Merchants' Association Cup; presented in 1949 by this Association for new varieties certified as showing tolerance to *Verticillium* wilt.

The judges were Messrs. John Morris, Dudley Le May and A. E. Quin with Lt. Col. F. N. Richardson as chairman of the judging committee.

Though the number of growers exhibiting (48) was exactly the same as in 1960 the number of entries (69) was five fewer. A list of entries together with the analyses carried out at Wye by Mr. J. B. Roberts is given below in Tables 1-3. The figures for alpha acids are very similar to those of the previous year but those for the beta resins are generally higher.

The Brewers' Cup (Table 1) was won by Mr. W. Phillips of Avenbury, Worcestershire with a sample of Bullion, with an analysis of 8·8 per cent. alpha acids and 12·2 per cent. beta resins. Three

TABLE 1

ENTRIES FOR BREWERS' CHALLENGE CUP 1961

Variety and Grower	Parish	Hops moisture free	
		alpha acids %	beta resins %
Bullion (Q43)			
W. Hoad	Hawkhurst, Kent	9·8	13·8
Guinness Hop Farms Ltd. ..	Teynham, Kent	9·3	14·6
,, ,, ,, ,, ..	,, ,,	9·0	12·6
*W. Phillips	Avenbury, Worcs.	8·8	12·2
†S. T. Adams	Tenbury Wells, Worcs.	8·6	11·1
R. D. Wickham	Brenchley, Kent	8·5	13·4
W. D. Hukins	Tenterden, Kent	8·5	12·3
Morphett Bros.	Nettlestead, Kent	8·4	12·4
James Nott	Tenbury Wells, Worcs.	8·3	11·9
E. M. Gorst	Brenchley, Kent	8·1	11·2
J. Dinnis and Sons	Shoreham, Kent	8·0	13·0
J. Turner	Bosbury, Worcs.	7·9	11·6
F. M. Day Ltd.	Marden, Kent	7·5	10·6
John Paine and Sons ..	East Sutton, Kent	7·2	10·1
Furnace Farm Ltd.	Lamberhurst, Kent	6·9	13·5
Wm. Alexander Ltd. ..	Shoreham, Kent	6·3	10·6
J. F. Bomford Ltd. ..	Fladbury, Worcs.	6·2	10·2
J. A. Worley Ltd.	Yalding, Kent	6·1	11·2
J. A. Worley Ltd.	Yalding, Kent	6·1	10·1
Guinness Hop Farms Ltd. ..	Bransford, Worcs.	5·6	12·6
Brewer's Gold (C9a)			
Guinness Hop Farms Ltd. ..	Teynham, Kent	9·2	12·4
Guinness Hop Farms Ltd. ..	Teynham, Kent	9·1	11·2
Kennington Hall Farms ..	Wye, Kent	7·3	9·3
E. L. Worsfold	East Sutton, Kent	7·0	11·2
College Cluster (N15 bis)			
Guinness Hop Farms Ltd. ..	Teynham, Kent	6·6	6·7
Guinness Hop Farms Ltd. ..	Teynham, Kent	6·3	7·7
Pride of Kent (170a)			
J. F. Bomford Ltd. ..	Fladbury, Worcs.	6·7	12·3
Copper Hop (OK40)			
J. F. Bomford Ltd. ..	Fladbury, Worcs.	5·6	10·3

* Winner of Cup † Considered to be a good sample.

other samples of Bullion gave slightly higher analyses. Another entry of Bullion also from Worcestershire but with a fractionally lower analysis was considered by the judges to be a good sample. Entries of

Brewer's Gold and College Cluster were the same as in the previous year, whilst Pride of Kent re-entered the list after a year's lapse. The Brewers' Cup has since its presentation in 1944 been won by a sample of Bullion every season except the first when it was won with Brewer's Gold. It is interesting to note that in 1944 out of a total of 25 entries 10 were Brewer's Gold and four Bullion whilst in this exhibition out of 28 entries 20 were Bullion and four Brewer's Gold.

TABLE 2

ENTRIES FOR GROWERS' CHALLENGE CUP 1961

Variety and Grower	Parish	Hops moisture free	
		alpha acids %	beta resins %
Northern Brewer (WFB135)			
Alfred Day and Sons Ltd. ..	Ulcombe, Kent	9·2	10·7
†T. L. Walker and Sons ..	Doddenham, Worcs.	8·9	9·9
Courage & Barclay Ltd. ..	Hunton, Kent	8·8	11·4
T. D. & H. Harris	Capel, Kent	8·3	11·6
James Nott	Kyrewood, Worcs.	8·2	9·9
H. Veall	Capel, Kent	8·2	9·0
Morphett Bros.	Nettlestead, Kent	8·1	10·8
Morphett Bros.	Nettlestead, Kent	7·8	10·5
*A. & K. J. Amos	Wye, Kent	7·7	9·9
E. L. Worsfold	East Sutton, Kent	7·5	8·9
W. H. Hoad	Hawkhurst, Kent	7·4	9·4
Wm. Alexander Ltd. ..	Shoreham, Kent	7·3	10·2
S. G. & K. J. Calcutt ..	Goudhurst, Kent	7·2	12·7
J. Dinnis & Sons	Shoreham, Kent	6·8	9·7
T. L. Walker & Sons ..	Doddenham, Worcs.	6·5	8·9
G. Nott & Co. Ltd.	Eardiston, Worcs.	6·2	9·7
J. F. Bomford Ltd.	Fladbury, Worcs.	6·0	10·5
Pride of Kent (170a)			
John Paine & Sons	East Sutton, Kent	7·2	13·9
W. D. Hukins	Tenterden, Kent	7·0	12·5
E. L. Worsfold	East Sutton, Kent	6·5	14·4
A. & K. J. Amos	Wye, Kent	6·4	13·3
Early Choice (FF21)			
J. & R. J. Pomfret	Lamberhurst, Kent	5·1	8·9
J. F. Bomford Ltd. ..	Fladbury, Worcs.	4·0	7·4
ON78			
J. F. Bomford Ltd. ..	Fladbury, Worcs.	5·6	8·0

* Awarded cup. † Judged to have a pleasant aroma.

The Growers' Cup (Table 2) was won by Messrs. A. and K. J. Amos with a sample of Northern Brewer with the moderate analysis of 7·7 per cent. alpha acids and 9·9 per cent. beta resins. A sample from a Worcestershire grower with 8·9 per cent. alpha acids was judged to have a very pleasant aroma. Once again the results in this class illustrate the relatively low value put on P.V. in English type hops. The varieties entered in this class were similar to that in the previous year but there was a drop of five in the Northern Brewer entries. Since its presentation in 1946 the Growers' Cup has been won 10 times with Northern Brewer, twice by Pride of Kent and once each by Brewer's Gold, Early Promise, Bramling Cross and the unnamed seedling ON78.

The Hop Merchants' Association Cup (Table 3) was won by Messrs. W. Reader and Sons with a sample of Bramling Cross having

TABLE 3

ENTRIES FOR HOP MERCHANTS' ASSOCIATION CUP 1961

Variety and Grower	Parish	Hops moisture free	
		alpha acids %	beta resins %
Whitbread's Golding Variety (1147)			
Whitbread & Co. Ltd. ..	Beltring, Kent	5·8	9·3
Whitbread & Co. Ltd. ..	Stilstead, Kent	5·7	9·1
Courage & Barclay Ltd. ..	Hunton, Kent	5·5	8·3
E. M. Gorst	Brenchley, Kent	5·4	9·2
†Whitbread & Co. Ltd. ..	Beltring, Kent	5·4	9·1
C. E. & W. S. Millson ..	Goudhurst, Kent	5·4	8·3
Furnace Farm Ltd.	Lamberhurst, Kent	5·2	8·8
W. Reader & Sons	Yalding, Kent	5·1	8·7
James Day Ltd.	Yalding, Kent	5·1	7·3
C. E. & W. S. Millson ..	Goudhurst, Kent	4·9	8·6
D. H. J. Britcher	Marden, Kent	4·3	8·4
Bramling Cross (OT48)			
G. A. & S. G. Calcutt ..	Goudhurst, Kent	6·3	9·0
C. E. & W. S. Millson ..	Goudhurst, Kent	6·0	9·0
*W. Reader & Sons	Yalding, Kent	6·0	8·8
C. E. & W. S. Millson ..	Goudhurst, Kent	5·8	7·7
Keyworth's Midseason (OR55)			
T. D. & H. Harris	Tonbridge, Kent	7·1	9·7
Density (D.1)			
D. H. J. Britcher	Marden, Kent	6·4	9·8

* Awarded cup. † Highly recommended.

an analysis of 6·0 per cent. alpha acids and 8·8 per cent. beta resins. A sample of Whitbread's Golding Variety entered by Messrs. Whitbread was highly commended. Competition for this cup now lies between Bramling Cross and Whitbread's Golding Variety. Keyworth's Midseason has virtually dropped out and as yet none of the new wilt-tolerants are making more than an occasional appearance.

APPENDIX II

THE 1961 HOP SEASON
WEST MIDLAND REGION

NORMAN MOSS
(*Hops Advisory Officer, West Midland Region, N.A.A.S.*)

SEASONAL CONDITIONS

The exceptionally high rainfall of 1960, which continued to the end of the year, had left the hopyards virtually waterlogged and much of the normal autumn work had been completely untouched.

The first three months of the year brought a great improvement and the spring operations were completed by the customary dates. The rain returned in April and over four inches were recorded during the month on the Rosemaund Experimental Husbandry Farm. Thereafter, dry sunny weather set in and continued, with only scattered showers and a few isolated storms, until the picking season was over. The soil dried quickly and harshly, and the crop suffered because of both a shortage of soil moisture and a general absence of a good tilth for the annual feeding roots.

The growth promised well until June, and then failed to continue development and remained too light to carry a heavy crop. It was particularly difficult to maintain sufficient growth in many Fuggle yards: Goldings did much better and some good yields of quality hops were produced.

The heavy crop of 1960 had been more than sufficient to meet the estimated market demand of 95 per cent. of the Basic Quota: the raising of this figure to 104½ per cent. for 1961 was welcomed by the hop growers although, in the event, this target was not reached.

PESTS AND DISEASES

The spring migration of aphis to the hopyards was on a large scale and continued over a long period. There was reason to think that the protection afforded in the late spring by the foliage-applied systemic insecticides was not so prolonged as usual: the slow movement of sap within the plant, and the rapid evaporation and volatilization of the insecticide on the foliage were suspected causes for this. However, the use of insecticides at less than the recommended rates was, in many cases, at least a contributory cause

for the need of frequent spraying. Aphis were not numerous in the late summer and the cones remained virtually free.

In spite of the dry weather, red spider mite was never in evidence. Several instances of hop root weevil damage were reported and there may have been a slight increase in the numbers of this pest.

Verticillium wilt was again widespread but there was no reason to suppose any new outbreak of the progressive form. The yards within a mile radius of the two progressive outbreaks confirmed in 1960 were again inspected by officers of the M.A.F.F. Plant Health Branch. The need for every individual grower to maintain effective precautions against the spread of this disease, and the early recognition of symptoms as the first step in achieving this, cannot be over-emphasized.

Basal spikes of downy mildew were not especially numerous, except perhaps in those parts of the yards where prolonged delay occurred in cutting down the bines which had not been picked in the previous autumn. However, the incidence of terminal spikes in many yards during the latter part of May was higher than had been previously experienced. In retrospect it would seem that the importance of the earlier incidence of downy mildew spots on the lower leaves had been underestimated. The removal of spikes, the application of protective fungicides, and a providential lowering of humidity checked the disease and downy mildew was not, in fact, a serious threat for the remainder of the season. The loss of so many main bines, and the dependence on laterals, resulted in uneven growth and a reduction in yield.

Powdery mildew became increasingly widespread as the hot, dry weather continued: it appeared first in yards with a known history of the disease but, later, spread to yards where it had been previously unknown. Considerable difficulty was experienced in checking this disease especially where specific control measures were delayed until the cones themselves were affected.

Stem canker (*Fusarium*) and root rot (*Phytophthora*) were responsible for an increase in the number of bine losses, following the waterlogged state of the soil during the winter. The few adventitious roots which developed on cankered bines failed to get sufficient nourishment from the dry top soil and water-loss exceeded water-uptake, with consequent wilting.

Nettlehead virus complex, once again, was the reason for extensive grubbing and replanting. The symptoms of mosaic and of split leaf blotch were rather less severe than usual.

Picking and Drying

The cones were slow to mature and they did not hang well. The colour and rub, in spite of hours of sunshine being above average, remained somewhat disappointing. Fuggles, as was remarked in 1959, were affected by green streaks of petals down the cones rather than the well-recognized green heel. The firm ground, light bines, and generally dry foliage provided excellent conditions for picking which was to a very high standard. Further picking machines were installed during the year and hand-picking is rapidly becoming the exception.

The high ambient temperatures, with low humidity, which prevailed during the picking season increased the difficulties inherent in the management of dried hops on the cooling floor, and this probably accounted for a certain degree of chaffiness in the samples.

APPENDIX III

THE 1961 HOP SEASON
SOUTH EASTERN REGION

CATHERINE L. JARY, B.Sc.(Hort.)
(*Hops Adviser, South Eastern Region, N.A.A.S.*)

The 1961 season was a difficult one for hops when a number of adverse factors combined to produce a light crop most of which was only of moderate quality. The basic cause for this situation was the weather, and trouble started with the very wet autumn and winter of 1960. Severe damage was caused to the soil and the hop roots in the course of picking. During the winter some hills were killed completely by waterlogging, but hops will stand a good deal of flooding when dormant and losses were lower than might have been expected. The root damage however gave the plants a poor start for the following summer and may have contributed to the early senescence of the crop in the dry season.

The spring and early summer of 1961 were unusually warm and growth was very forward. However, a severe outbreak of secondary infection of downy mildew in the form of terminal and lateral spikes occurred in April and May, resulting in the loss of much early bine. The remainder of the summer was dry and windy, constituting an unfavourable combination of conditions following the wet winter. Wind damage was quite marked in East Kent with its poor natural shelter.

The other cause of serious loss of crop in this region was progressive *Verticillium* wilt which appeared unusually early and spread very rapidly towards the end of the summer. The quality of the crop was adversely affected by mould (the prevalent disease of dry summers), and in some cases this was bad enough to cause appreciable loss of crop as well.

DISCUSSION OF YIELDS PER ACRE

In years when all the crop is picked to fulfil quota requirements a comparison of yields per acre in the separate areas of the region is interesting, particularly in observing the trends over past years. In 1961 the outstanding feature was the relatively poor performance

of East Kent which normally yields well in a dry summer and until this year had always produced the highest yield per acre of all districts. Now however, this position is held by Hampshire and although the 1961 crop reflects marked climatic differences between the two areas, there has for some years been a tendency for yields in Hampshire to rise and those in East Kent to fall. The Weald, with a relatively high proportion of shallow and badly drained soils, always suffers in a dry summer and since it is still largely growing Fuggle, has heavy losses from wilt as well. Mid-Kent, an area much affected by wilt, is now extensively planted with wilt-tolerants, but its present yield is consequently depressed by the high proportion of young hops. Sussex and Surrey have always shown large fluctuations and there is now enough wilt in Sussex to affect the average yield since it is still very largely a Fuggle area. In both counties however there has been, over the past years, a tendency for yield per acre to improve relative to Kent.

Main Problems

The main problems exercising the minds of growers in the South East as indicated by advisory queries and topics of discussion, could be listed as follows, although not necessarily in order of priority:

Verticillium Wilt

The practical control of this disease hinges on the growing of wilt-tolerant varieties and has largely become a question of propagating sufficient good stock. The technique of mist propagation, worked out by the late Dr. Williams at Wye College, was tried by a few growers in the summer of 1961, and was the subject of an advisory campaign during the autumn and winter. It will fill a great need in providing the means for a sufficiently rapid build-up of suitable varieties.

Fortunately, the trade appears to have completely accepted W.G.V. and now regards Bramling Cross as acceptable provided that it is the true stock with a mild aroma. Janus also is being given a fair trial so that the question of varietal suitability is less acute than for many years.

At the same time recent work by East Malling Research Station on the effect of a pure grass sward in starving out *Verticillium* supports the advisory recommendation to eliminate or restrict the spread of new outbreaks of wilt by grassing down the affected area. This work also suggests some hope of a possible rotation for growing wilt-

sensitives, though no firm recommendation can be made about this at present.

Downy Mildew

The importance of this disease was brought home to growers in 1961 by the severe outbreak of spike already mentioned, and also by the killing and weakening of the rootstocks in W.G.V. The importance of control measures early in the season has now been established experimentally and emphasized in lectures and individual advice, and this knowledge should prevent similar catastrophes from occurring in future.

Virus Diseases

These are very widespread and constitute an insidious and unknown drain on production. They are really the least understood of all the problems of hop growing, but although serious for some growers, they are not so important in this region as the other problems listed. In practice it is found that mosaic is only serious where carrier varieties are mixed with sensitives or grown adjacent to them. Nettlehead is more difficult in that it appears to persist for long periods in certain sites and in such gardens cannot be overcome by grubbing and replacement with healthy stock. At other sites however this practice is satisfactory for several years, but at present it is not possible to predict what will happen on any given site. Split leaf blotch has always been very widespread in commercial stocks of Fuggle but the large scale planting of good stocks of Fuggle N has gone a long way towards reducing this problem, at least for the time being.

Machine-Picking

This really comprises two problems: first, the actual management of picking: and second, the whole practice of growing hops for the machine. The latter may involve modification of the wirework and also of traditional cultural practices if quality and yield per acre are not to be sacrificed.

Hop Drying

The recent changes in the practice of hop drying involving the use of more powerful fan/furnace units to produce higher air speeds, are to some extent a by-product of the practice of machine picking. Growers are also interested in other aspects of the problem such as simplication of procedures, the elimination of unnecessary

handling and the concentration of drying on to a smaller kiln area to reduce the maintenance of unnecessary structures.

The final comment of the year, recapitulates the first statement, namely, that in spite of all the growers' efforts it is really the weather which ultimately determines the crop, both in terms of quantity and quality, and over that we have no real control, although some of its direct effects can be mitigated by drainage, irrigation and the provision of shelter.

APPENDIX IV

A NOTE ON FIELD TRIALS ON THE CONTROL OF BASAL SPIKES OF HOP DOWNY MILDEW BY HILL DUSTING WITH COPPER FUNGICIDE

CATHERINE L. JARY, B.Sc.(Hort.)
(*Hop Adviser, South Eastern Region, N.A.A.S.*)

SUMMARY

An observation study on hop downy mildew in which Bordeaux dust was applied at various times to hop hills, was carried out at two sites for 5 years. The results indicated that application of dust in April—at early shoot growth—together with regular removal of basal spikes, effected a reduction in the number of early spikes. Removing these spikes alone was not sufficient to prevent an increase in their incidence. It was also observed that the bulk of basal spikes was produced by relatively few hills, and evidence was obtained to suggest that grubbing hills showing several spikes early in the season would be a practicable and useful measure for reducing hill infection.

Dusting hills with copper fungicide for the control of downy mildew was originally studied at Wye College in 1932 and 1933 (Salmon and Ware, 1933; 1934) but was pronounced ineffective as no appreciable reduction in the number of basal spikes was obtained. At that time, the official advice to growers was that there was no point in grubbing hills showing infected strap cuts at the time of dressing. No further research was done on this problem for more than twenty years, but during this time downy mildew became increasingly troublesome.

In 1954 hops in the South Eastern Region were badly affected by downy mildew and it was thought desirable to try hill dusting again, particularly since a number of growers still practised it and claimed some benefit. The original pilot study was carried out in the spring of 1955 in a hop garden at Selling in Kent which had suffered a bad attack on the cones in the previous year. The result suggested some benefit from dusting, but after only one year's records, the whole garden was grubbed because of falling quota.

In 1956 two new sites were found at Boughton-under-Blean, Kent, in gardens where the grower reported unusually high mortality of hills and failure to grow sufficient bine. It was thought that downy mildew might be an important contributing factor. On one

site the hops were stated to be Bramling Goldings planted in 1950; the other site was an old garden planted with the Golding Variety, Cobbs.

The fungicide used was dry Bordeaux powder shaken on to the hills by hand from a bag. The dosage per application was not determined but was of the order of 15-20 lb. powder per acre. The following treatments were given:

(*a*) Hills dusted once during December-January (before dressing).
(*b*) Hills dusted once during March (a few days after dressing, allowing time for cut surfaces to dry).
(*c*) Hills dusted once during April (early shoot growth).
(*d*) Hills not dusted (control).

Treatments, begun in 1956, were applied and records taken on the same hills for five consecutive years at both sites—in contrast to the earlier work at Wye College when a separate group of plants was treated in each year. Weekly records of basal spikes were made and the spikes were pulled out at the time of recording. In the sixth year (1961) one record only, of the earliest spikes, was made at one site on the eight rows of the plot itself and on four adjacent rows on either side which had not received any dust and which had been spiked in the ordinary farm routine.

No more than one application of fungicide per annum was made for each treatment. This represents a light dosage compared with from three to six applications per annum made in hill dusting trials initiated in 1957 at Wye College (Coley-Smith and Beard, 1960). While no reduction in spikes was in fact obtained from dusting in December-January or in March, dusting in April reduced the incidence of early spikes at both sites.

In the early years of the study, the main effect at one site was the marked reduction in spike counts throughout the whole plot and this was thought to be largely due to the regular hand-spiking which they received. The remainder of the garden was spiked less frequently by the farm staff. In 1961 counts of early spikes were made in the four adjacent rows on either side of the plot area to compare the effect of less frequent spiking and no dusting with the four experimental treatments with regular weekly spiking. The control plots were found to show a degree of infection very comparable with that of the adjacent untreated rows in the garden, indicating that frequent hand-spiking was not by itself sufficient to prevent an increase in early spikes over a period of years.

Another important point which emerged from these trials is that basal spikes were not evenly distributed throughout a garden, but that the bulk of them were produced by relatively few hills. These hills usually threw several spikes early in the season and continued to do so throughout the same year and in subsequent years. If such hills could have been identified and grubbed the spike problem would have been greatly reduced. Such treatment combined with efficient hand-spiking and protective dusting of the remaining hills could provide a method of cleaning-up established gardens. From a study of the trial records it was found that the hills with the worst spike records could have been picked out in the first year as those showing three or more early spikes. On this basis, 10 per cent. of the total hills would have been selected and these produced 50 per cent. of the total spikes in the first year and 40 per cent. in the subsequent 4-year period. It is essential to combine the two features of *several* spikes (in this case, 3 or more) and *earliness* since it was found that hills showing only one or two early spikes did not nceessarily continue to produce more, while hills showing several spikes later in the season might not be troublesome in subsequent years if these spikes were removed promptly.

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